THE SOYA BEAN

ITS HISTORY, CULTIVATION (IN ENGLAND) AND USES

By

ELIZABETH BOWDIDGE

Foreword by

SIR JOHN T. DAVIES, K.C.B., B.Sc.

(Director, Ford Motor Company, Ltd.)

OXFORD UNIVERSITY PRESS

LONDON : HUMPHREY MILFORD

1935

OXFORD
UNIVERSITY PRESS
AMEN HOUSE, E.C. 4
London Edinburgh Glasgow
New York Toronto Melbourne
Capetown Bombay Calcutta
Madras Shanghai
HUMPHREY MILFORD
PUBLISHER TO THE
UNIVERSITY

'RINTED IN GREAT BRITAIN

FOREWORD

by SIR JOHN T. DAVIES.

THE British farmer is by tradition and experience extremely conservative, and it is a most difficult task to induce him to add another crop to those he is already growing, very often at a loss. The cultivation of the soya bean in this country must, therefore, for a few years at least, be the work of pioneers who are prepared to spend both time and money during the initial period of trial and experiment. It is for those who are willing to undertake this task that this book is primarily written. So far as I am aware no such work on this interesting subject has yet been produced in this country, partly because British agriculturalists have not yet realized the immense importance of the soya bean plant and partly because it has been considered difficult, or almost impossible, to grow it in a soil so far removed from its native environment.

In past years no sustained effort has been made to grow the plant on a large scale in England. The Royal Agricultural Society devoted several years to experiment at Woburn, but in 1914 they reported that the plant was quite unsuitable for growth in this country as it required more warmth than could be obtained here. The British Board of Agriculture reported in 1916 that 'the Japanese and Manchurian varieties hitherto tested cannot be relied upon to produce seed in this country. As the plant appears to be a very variable one, however,

it is not impossible that a variety suited to conditions in this country may yet be produced' . . . and the matter appears to have been left at this point.

Attempts to grow the bean in the United States of America began about the same time as in this country. The plant was cultivated first in the south, later as success was achieved in the middle states, and finally as far north as Michigan. In the year 1931 America exported large quantities of beans to Europe, and reports from European mills stated that the consignments were quite satisfactory.

Mr. J. L. North, late Curator of the Royal Botanic Society of London, is, I believe, the only person in this country who has consistently believed that it is possible to acclimatize the soya bean plant to English conditions, and through his knowledge of Natural Science coupled with an enthusiasm which deserves success, he has grown a bean which has accustomed itself to the soil of Great Britain and the vagaries of its climate. Articles on the results of Mr. North's work have been published in the Press from time to time, but they have not received the publicity and notice which they merit, and Mr. North has continued to plough a lonely furrow.

In 1932 Mr. Henry Ford acquired an estate of about 2,000 acres at Boreham, Essex, and not content to follow the usual orthodox methods of farming he suggested that part of the land should be devoted to the cultivation of the soya bean. Mr. Ford had already succeeded in harvesting large crops of the bean on his property near Detroit, and being convinced of its value as a soil improver and forage crop, and realizing the immense possi-

bilities of the by-products obtained from the seeds, he was anxious that an endeavour should be made to grow the plant in England. Accordingly, a quantity of seed was dispatched from Michigan to Essex, and it was arranged to make an experiment on a six-acre field specially prepared for the purpose. The soil was light loam with gravel sub-soil, and the weather during the growing season was somewhat warmer and drier than the average for that county at that period of the year. It was soon apparent that the attempt would be a failure, and that it would be useless to expect the plants to reach maturity, but, judging from the crop grown on the same estate in the following year (an account of which is given in detail in this book), it is now evident that the failure of 1932 was not due to unsuitability of soil or climate.

It was fortunate that at this period an illustrated article written by Mr. North appeared in the Press, in which he gave an account of a very successful crop which he had grown on a piece of land situated in the Thames Valley to the west of London. It was, therefore, decided to enlist the services of the only man in England who had by his own efforts and perseverance raised a crop which, from the size of the plants, the yield of the crop, and the analyses of the seeds, was comparable to anything grown in the United States, if not in Manchuria itself. But this success was only obtained as a result of experiments lasting over eighteen years! By careful selection, patient research, and intelligent observation of the plant's habits Mr. North has eventually triumphed over innumerable difficulties, and at the end of 1932 he had in his possession four varieties of seed from which, he was confident, a crop

could be grown successfully in this country. A quantity of these seeds was purchased and placed at the disposal of Mr. Henry Ford's manager at Boreham, Essex, and the story of the successful crop raised in 1933, and subsequently in 1934, is told in the body of this book.

The author, through association with Mr. North and by reason of her connexion with Fordson Estates Limited, has had a unique opportunity of observing the whole range of operations involved in growing the soya bean crop from the time of soil preparation to the storing of the grain. She has collected and studied most of the available and reliable literature on the subject and has lost no opportunity, by interview and otherwise, of making herself acquainted with all the knowledge that is at present obtainable regarding this Wonder Bean. The information has been summarized in this book. It does not pretend to be a comprehensive study of the subject. As the author explains, its purpose is to arouse interest and to draw public attention to the immense importance of the bean. In this I hope she will succeed. A bean which has been one of the staple foods of the inhabitants of north-eastern Asia for thousands of years, and which is so rich in fat and protein and the vitamins necessary to life should receive the serious attention of the peoples and governments of all countries. In calling the attention of the British people to this wonderful product of Nature the author has rendered a public service.

PREFACE

IN writing an account of the soya bean in a country where so little knowledge on the subject exists, and where practical experience in its culture is negligible, it has been found necessary to draw from the published accounts of the results of experiments carried out in other countries.

That very able and unique work *The Soybean*, by Messrs. Piper and Morse, has been my principal source of information. Various Bulletins issued by Agricultural Experiment Stations in the United States and Canada have also been invaluable. I have further supplemented my knowledge by personal correspondence with Mr. Morse, and I desire gratefully to acknowledge the help given by him.

The purpose of the book is to arouse interest in the cultivation and many uses of the soya bean, and to place before the British agriculturalist the relevant facts concerning its growth. While supplying information which, it is hoped, will be of value to the agricultural student I have attempted to avoid making the book too technical for the farmer. If it helps to show that the bean, now successfully acclimatized to the soil and weather conditions of England, can be grown profitably, and eventually on a commercial scale, its purpose will be amply served.

E. B.

- Soy beans
  - Plant
    - Forage
    - Pasture
    - Green Manure
      - Hay
      - Ensilage
      - Soilage
      - Straw
  - Seed
    - Oil
      - Soap Stock
        - Soft Soaps
        - Hard Soaps
      - Enamels
      - Varnishes
      - Paints
      - Rubber Substitutes
      - Food Products
        - Salad Oils
        - Lard Substitutes
        - Butter Substitutes
        - Edible Oils
      - Linoleum
      - Printing Inks
      - Lubricating
      - Lecithin
      - Waterproof Goods
      - Celluloid
      - Petroleum
      - Lighting
      - Explosives
      - Glycerine
    - Food Products
      - Dried Beans
        - Soy Sauce
        - Coffee Substitutes
        - Soups
        - Sprouts
        - Roasted Beans
        - Baked Beans
        - Vegetable Milk
          - Confection
          - Casein
          - Milk Powder
          - Condensed Milk
          - Cheese
            - Fresh
            - Dried
            - Fermented
            - Smoked
        - Confections
        - Meat Substitute
      - Green Beans
        - Canned Green Beans
        - Green Vegetables
        - Salads
    - Oil Meal
      - Flour
      - Diabetic Foods
      - Infant Foods
      - Macaroni
      - Breakfast Foods
      - Feeds
      - Glue
      - Fertilizer

Reproduced from *The Soybean* by PIPER & MORSE

CONTENTS

LIST OF ILLUSTRATIONS

A typical example of the soya bean plant grown at Boreham in the County of Essex in 1933. The photograph shows the plant at full maturity and dried ready for threshing

INTRODUCTION

THE soya bean with its many and varied uses is the most remarkable of all legumes, yet it is only within comparatively recent years that its real value has been fully recognized in Western countries. The slow advance of its cultivation in Europe is probably accounted for by the fact that it is difficult to acclimatize, but, within recent years, this feat has been accomplished and soya bean plants have been grown in Essex and harvested in the beginning of September 1933 and 1934 from seed acclimatized to English weather conditions. It is impossible to over-estimate the far-reaching consequences of this achievement to British agriculture if it is eventually proved that crops can be grown here on a profitable commercial basis.

The soya bean plant is easy to grow and to harvest. It has a high seed-yielding capacity and, being a legume, it is valuable as an improver of the soil for succeeding crops. In the United States of America it is grown for seed, hay, forage, and pasturage, and as it has been found more profitable than oats it has practically replaced that cereal in rotation plans. Up to the present time interest in the soya bean has been confined mainly to the oil obtained from the seed which commands a high price and is useful in so many trades, and to the by-products, cake and meal, which are high-grade stock feeds. The bean has another and equally valuable property which has become the subject of serious attention both in Europe and America. It has an exceptionally high protein value and contains two of

the vitamins necessary to life so that it may be profitably utilized in the production and improvement of foods for human consumption. According to the testimony of those who have made a study of its possibilities the soya bean could be made the mainstay for feeding a country in time of war. For our own country especially with its insular position its value ought to be thoroughly investigated and an intensive, concentrated effort should be made to grow it. Notwithstanding the lead given by America, no serious attempt to grow the plant in Great Britain has been made, and except for a few leaflets tucked away on the shelves of its library the Ministry of Agriculture admits having little knowledge of the subject. But for the isolated experiments of Mr. J. L. North, to whose foresight and perseverance the country owes a debt of gratitude hitherto unacknowledged, the sporadic attempts of expert growers like Sutton's of Reading and a few enterprising farmers here and there up and down the country, nothing has been done to encourage the cultivation of this very valuable legume in England. It may be that as the merits of the soya bean become better known belated efforts to cultivate it will be made, but there ought to be no delay, for the selection and acclimatization of varieties which will mature here is a matter of years of careful research and trial. The germinating power of the seed is not retained indefinitely; a considerable decrease in viability occurs after the second year. A few years before the late war a certain variety of soya bean seed, acclimatized to the soil and weather conditions of Germany, was brought over to this country with reports of satisfactory results. Inquiries were made as to the possibility of forming a syndicate to grow it in England, but the scheme did not develop. The Great War intervened and, apparently, this particular seed was

allowed to lose its viability, for efforts to grow and bring the plant to maturity are still being made in Germany, though with no great success—one of her foremost agriculturalists gave up cultivating the plant two years ago after trying for many years. The experience gained on an enterprising estate in Essex in the years 1933 and 1934 shows quite clearly that four varieties of the soya bean which have been acclimatized by Mr. North are definitely capable of being grown and brought to maturity successfully in England, and the Ministry of Agriculture and other public bodies should encourage officially, and with energy and vigour, an undertaking which in these instances proved an undoubted success. A sustained effort should be made under Government supervision to investigate the qualities of the bean, and the best brains of our leading chemists enlisted to carry out researches into its food value. The staple foods of the people may be said roughly to consist of meat, bread, butter, and milk. It is claimed that the soya bean is rich in all the ingredients that enter into the composition of these four items of the essential daily nourishment of the population. The extraction of the protein, fat, and other valuable contents of the bean and their transformation into substances suited to the palate and digestion of the human body is a matter, at present, being assiduously carried out in the laboratories of the United States and Germany; it can only be done in this country if the Government undertakes to do it officially. The Department of Scientific and Industrial Research already exists—what more profitable work could it be engaged upon than to concentrate the minds and energies of its chemists on extracting from the soya bean those substances with which Nature has endowed it, and making them available for human consumption not only in time of peace but also as a guarantee

against privation, and perhaps starvation, in time of war.

It is surprising how little is known of the soya bean in this country. The extraordinary number of its uses is almost unbelievable. The bean contains about 46 per cent. of protein and, unlike the protein of other common legumes and cereals, it is rich in the amino acids which are essential to the normal growth and maintenance of the human body. The fat content shows a range of 12 to 24 per cent. and equals the average of meat fat with the added advantage of being more easily digested. The carbohydrate, water, and ash contents average 26·50 per cent., 7·50 per cent., and 5·50 per cent. respectively, and the calorie value is nearly 2,000 to the pound, which is only excelled by the pea-nut. The almost entire absence of starch points to its use in foods for persons requiring a low starch diet; it is of value to those suffering from rheumatism who must abstain from meat because of its tendency to encourage uric acid, and it helps, very largely, to solve the problem of the vegetarian.

The bean yields a valuable oil, and by-products in the form of cake and meal which are used in cattle feeding. The oil is used in paints, varnishes, lacquers, and enamels, in the manufacture of linoleums, oilcloths, and other waterproof goods, rubber substitutes, printing-ink, &c., and it has a further use as lubricant and core-oil in foundry operations. After deodorizing and refining the oil finds a very ready market in the margarine industry, and for culinary purposes it appears as cooking and edible oil. There is a very large demand for the oil in the soap-making industry in America. Glycerine and casein are obtained from the bean, and glues and adhesives made from the oil-free meal frequently replace other vegetable

glues used for veneers and plywoods. The oil-free meal is also used in the manufacture of a bakelite substitute. A very recent development in the uses of this remarkable bean is the manufacture of motor-car parts such as steering-wheels, gear-shift knobs, and distributor parts. A synthetic resin is being produced from it for use in the making of a special enamel for motor-car body work. The enamel is said to be superior to lacquer from the original gloss to its resistance to deterioration.

Owing to its high protein value the soya bean has a further use in foods for human consumption. Soya flour is already available in England. It is used to make breakfast foods, biscuits, bread, cakes, macaroni, and numerous other food products among which are preparations for infants and invalids. The dried bean provides a coffee substitute, fresh and condensed milk, various sauces, soups, and cheese in the dried, fresh, and fermented forms. The green beans may be used in salads or as green vegetables and a small-seeded variety produces 'sprouts' which are stated to be very palatable and nutritious.

In farming operations the plant provides seed, hay, and straw; it may be grown as an improver of the soil for succeeding crops or as a green manure to restore the fertility of poor, thin soils.

It has been said, and it seems with truth, that a country growing the soya bean provides food for its people, its cattle, and its guns!

II

THE SOYA BEAN IN THE EAST

THE soya bean is a native of eastern Asia and one of the oldest crops grown by man. Its cultivation dates back to China's agricultural age and is said to have been in practice more than five thousand years ago. Ancient books of China state that it was one of the staple articles of diet centuries before such books were written, and it remains an important food of the masses to-day. It is ground in the mills; it is hydrogenated into a form of vegetable lard; the caked residue of oil extraction is re-ground and used as food for man and beast. It is a source of the 'milk' supply in the East. To the Oriental the soya bean is more than a food; it is his safeguard against famine and the country's 'coin of the realm'.

The production of the bean in the East is concentrated in two regions in the eastern part of China including the three provinces of Manchuria, Japan, Korea, and certain parts of Inner Mongolia. The soya bean is relied upon by the Manchurian farmer as a cash crop. It occupies about 25 per cent. of the cultivated area and is grown largely for oil and meal. The credit of realizing the value and commercial possibilities of the bean belongs, undoubtedly, to the Japanese, although it has been cultivated from time immemorial by the Chinese. Previous to 1907 trade in the soya bean was confined to China and Japan with Manchuria as the base. It was not until the opening of the Newchwang Railway brought the interior of Manchuria into communication with the sea that it became known outside the Orient. It was just after the close of

the Russo-Japanese War (1904–5) that the first trial shipments came westward, and they were sent by Japanese firms with the hope of finding a market for the huge stocks of beans which had been grown to supply war-time needs. Japan is a large consumer of the Manchurian bean, although the cultivation of the plant occupies an important part of her own agricultural pursuits. Large quantities are imported for oil extraction and for the production of bean-cake which is used in that country for fertilizing purposes as well as cattle feeding. Japan grows the bean mainly for the grain, and her home-grown bean, being considered superior to the imported variety, is used exclusively for food purposes. The utilization of the soya bean in food products may be said to have been brought to a fine art in Japan, where it forms one of the important articles of the diet. In one form or another it appears daily in Japanese homes, and innumerable dishes in endless variety are prepared from it. Soya food preparations are eaten by rich and poor alike. For the poorer classes it forms one of the principal sources of protein. The beans are powdered for use in soups, they are picked green, cooked, or served cold with salads, and the matured bean is used as an ingredient in numerous fermented food products. The dried bean is soaked in salt water and roasted after the manner of the salted peanut and, in the absence of animal milk, it provides a vegetable milk which is used extensively throughout the East. The oil, consumed in the crude state by the very poor, or boiled and clarified among the rich, is also an important article of food. One wonders what the people of the Far East would do without the soya bean! One of the reasons why Manchuria has become of such enormous importance to Japan is the urgent need of commanding a cheap and ready food for her increasing population. Manchuria has gold, iron,

coal, and minerals, but surely the real prize is the soya bean. Japan has large capital invested in Manchurian mills and there are very big profits in the transport of the bean as it travels round the world.

THE SOYA BEAN IN EUROPE

The advance of soya bean trade in world commerce is one of the remarkable events of modern times. Thirty years ago the bean was almost unknown outside the Orient—at the present time it holds an important and firmly established position among the imports of practically all European countries. Huge quantities are imported for the extraction of oil, and a steady trade is carried on in the re-export of the by-products.

The first successful shipments from the East began in the year 1907 and, as an important source of vegetable oil, the beans soon found a market in English oil-mills. The oil began to be used in the soap industries. Most of the first large importations were received by England and for a few years she ruled the market partly because the bean was free of tax whereas France, Italy, and others paid duty on beans. When once its economic importance was recognized the removal of the impost in other countries was not long delayed, and when Europe and America entered the lists the monopoly of trade in soya passed away from England.

Trade developed steadily until 1914, when the Great War put an end, for the time being, to activities. Since the post-war revival trade has expanded rapidly and demands for soya increase year by year. The report of one line of transport shows an increase of over a 100,000 tons in 1933 over the previous year. The official publication of the Suez Canal Company—*Bulletin Decadaire*—

gave the actual quantities of soya beans passing through the canal as 1,580,000 tons in 1933 as compared with 1,442,000 tons in 1932. Great Britain imported 158,000 tons in 1932, and Germany's tonnage was well over the million. The Table below deals with four European countries only and serves to show the yearly increase in demand. For the sake of clarity the figures have been rendered on the English tonnage basis.

Imports of Soya Beans for the Years 1930–2

Year	*England* tons	*Germany* tons	*France* tons	*Denmark* tons
1930	91,309	874,054	539	170,000
1931	110,300	998,266	10,640	230,000
1932	158,935	1,167,914	14,289	230,000

The soya bean has been grown on a small scale in most European countries. France, Germany, Italy, Switzerland, and Holland have each made trials with more or less success but climatic conditions are, apparently, against the successful cultivation of the plant, for it has never, in any one case, attained the position of a field crop. The Royal Botanic Gardens at Kew is said to have grown a specimen as a curiosity as early as 1790. In the past, efforts to bring the plant to maturity in this country have not been attended with outstanding success. Factors contributing to failure were, no doubt, the use of seeds of unknown origin and the absence of knowledge in the matter of its culture. Later, seeds from known localities were used with more success but not sufficient to warrant further trial. Efforts to introduce the bean to English agriculture were begun in 1909 and given up in 1914, and except for the work of Mr. J. L. North nothing further has been done.

THE UNITED STATES

The soya bean was introduced into the United States of America about 1804, but more than fifty years passed before several varieties were put under trial and general interest began to be aroused in it. Serious experiments in its cultivation were started in 1908, and it soon became established as a farm crop grown mainly for forage. It was not until after the Great War that the bean began to attain commercial importance in the States, and this was chiefly due to the development of the oil-extracting industry. It is now a crop of great importance, and America supplies her own oil-mills with thousands of tons of domestic-grown beans annually. The extensive data to be found on the subject of the bean, and its cultivation and uses, is a tribute to the enormous amount of work carried out by United States Experimental Stations and laboratories. From 1914 onwards the bean and its by-products were imported into America on a gradually increasing scale. In that year 8,000 tons of oil, 900 tons of beans, and 1,500 tons of bean-cake entered the country. Six years later these amounts had increased to 56,000 tons of oil, 1,400 tons of beans, and 12,000 tons of bean-cake. (The amounts are approximate and are merely given to show the development of U.S.A. trade in soya in six years.) Since 1920 America has been seriously engaged in cultivating the bean herself, and by 1926 twenty-two states were contributing to its production. The emergency tariff measure of 1921 and the increased tariff duties of 1930 stimulated domestic production, with the result that 15 million bushels (or approximately 400,000 tons) of gathered beans was reported for the year 1931. In 1931, for the first time, American-grown soya beans were exported to European markets, chiefly to those of Germany

The soya bean has entered America to stay. Her farmers are seriously occupied with its cultivation. Experimental Stations issue new information and questionnaires to farmers all over the country; chemists are hard at work studying the possibilities of the home-grown bean and adding day by day to the already long list of its uses. Acreage has increased rapidly. In 1910 about 2,000 acres was devoted to the cultivation of the bean; reports for the year 1920 gave 950,000 acres (of which 80 per cent. was utilized for forage), and it is estimated that the present acreage is somewhere in the neighbourhood of 5,000,000. With advanced methods of cultivation, and first-class machinery to counter-balance cheap Oriental labour, the European markets seem wide open to America. The beans exported in 1931 were considered superior to those coming from Manchuria and they were well received. The situation in the East at that time was very unsettled and prevailing prices made competition possible. It appears to be only a matter of time before the United States of America will be in a position to compete with the Orient in raising the soya bean for her own needs and in supplying Europe with both the bean and its by-products.

The enormous tonnage required by the European trade is continuous. Germany buys more than a million tons of beans annually, but she purchases on the basis of protein content; her soya meal is expected to reach the 46 per cent. protein level. America's bean contains from 35 to 36 per cent., the Manchurian variety 36 to 38 per cent.—in England, a bean containing 46·26 per cent. protein can be grown. Here is a very real reason why Great Britain should grow soya beans!

CANADA

Reports from Canada show the soya bean to be a subject of increasing interest. Canada grows the plant for seed, for cattle feeding, and industrial purposes. Less than 1,000 acres was used for the crop in 1929, but during the last five years there has been a great increase, and 15,000 acres was reported for the year 1933. A great deal of research work has been carried out in the past ten years with early maturing varieties, and in the selection of varieties adapted to wider range of soil and climatic conditions. At present the cultivation of the bean is confined chiefly to the Province of Ontario, but the area is extending further and soya is gradually taking a place among Canada's important field crops.

III

DESCRIPTION OF THE PLANT

THE soya bean plant is an erect, bushy leguminous annual with a woody stem ranging in height from 1 to 5, or even 6 feet. It is much branched and carries heavy foliage and very small mauve or white flowers. The flowers are borne in axillary clusters and are self-pollinating. They appear first at the base of the main stem and progress upwards towards the top, the same order obtaining on the branches. The period of flowering is comparatively short, usually about three weeks. The pods appear in groups of three or four and carry from two to three seeds each, with four occasionally and five not unknown. The length of the pods is from 2 to 4 inches, following the shape of a scythe. The seeds vary in shape and may be round to elliptical according to variety, and the colour may be brown, green, black, or yellow, or various combinations of these colours. A good full-grown specimen of the soya bean plant is a mass of pods ranged in groups one above the other. The leaves are usually tri-foliate, but variation occurs here also according to the type of plant, and the stem and pods are covered with fine short hairs which are harsh to the touch. As full maturity approaches the leaves turn yellow and fall, and the plant stands bare except for its load of pods. The plant has an upright habit of growth and the branches, instead of growing equally round the stem as with most plants, are developed in one plane like fingers on a hand. This habit of growth has been fixed through many centuries by Chinese methods of cultivation. Even though the plants are grown wide apart so that there is plenty of room to

spread this flattened habit persists, and if the plant has started from the seed in a way which brings it into a wrong angle with its neighbours it bends itself round to get into line, the twist at the junction of the stem and root showing this very plainly when the plant is uprooted.

Glycine soja, the wild plant from which the soya bean is derived, is a twining vine with more slender stems and smaller leaves, pods, and seeds than the cultivated variety. The types acclimatized to English weather conditions are very woody at base, range from 12 to 30 inches in height, have flowers forming in clusters, and small numerous pods. There are thousands of different varieties of the soya bean. According to the *United States Year Book of Agriculture* (1933) more than 7,000 samples have been collected since the Department first began to introduce soya bean varieties. In this very large collection there are more than 2,000 distinct types requiring from 75 to 200 days to reach maturity. At present, about forty different varieties are grown in the United States, and these are constantly being added to, or deleted from, as new and better varieties are found.

The soya bean is very sensitive to environment, so much so that it often refuses to grow in one locality while it flourishes in another. Cases have been reported where seed from a successful crop would not grow in an adjacent field. For the best results in yields each region grows varieties specially adapted to it. In the countries of the East different regions grow different varieties for specific purposes. In Japan, for instance, where the bean is used extensively as a green vegetable, more than sixty different varieties are grown solely for this purpose.

The soya bean plant at full maturity. A comparison with Plate 1 shows the amount of shrinkage brought about by drying

RESULTS OF EXPERIMENTS IN ENGLAND

One of the first attempts to acclimatize the soya bean in England began in 1914 at the Royal Botanic Gardens, Regents Park, when it was shown by Mr. North that certain varieties could be 'advanced' sufficiently to produce a mature crop towards the end of September. Many years devoted to careful selection of seed from the varieties in his collection had resulted in several early strains. In 1928, a hybrid was received from Canada which, on passing the experimental stage, was planted out on a number of small plots in various parts of the country. It proved to be a very reliable cropper and matured earlier than any of the sixty varieties previously under test. Planted in the first week in May it was harvested at the beginning of September, and reports of good results came from Middlesex, Essex, Berkshire, Oxfordshire, and Hampshire.

The largest experimental test ever conducted in this country took place in 1933 at Boreham, Essex, when forty-seven different varieties of the soya bean originating from North America, Canada, Manchuria, and Japan were grown under observation. The selection included four varieties which had been acclimatized by Mr. North. Mr. North was engaged to supervise operations, and 50 lb. of his special seeds was purchased. The results obtained were most interesting.

The seeds were sown in three different sections of the estate each having different types of soil. One plot was light loam previously in fallow, another was an ordinary vegetable garden attached to a house, and the other was a piece of park land recently brought into cultivation. Abnormally fine weather prevailed from May onwards

continuing throughout September and well into October, and Essex, even more than other counties, suffered from drought. The growing season began in May and ended in September. The seeds were sown in rows, the acclimatized varieties being planted by hand and the foreign seeds being drilled in some cases and sown by hand in others. Germination was regular on all plots, and the plants took from 10 to 14 days to appear above ground. At the end of May some varieties had reached a height of $3\frac{1}{2}$ inches, and at the end of June 9 inches. Flowering began in July and continued throughout August.

At the beginning of September several of the foreign varieties were carrying very small pods which were not likely to mature and many had not passed the flowering stage. A few podded exceptionally well but were not near maturity at the end of September. Some showed pods in the early stages of development which did not fill out at all; many bloomed but did not pod; others produced blossom and young pods too late in the season, and many did not even bloom. Among this large selection of foreign seed were several varieties particularly suited to hay production, namely, those carrying heavy foliage on slender stalks with pods forming but failing to fill out. Some of these plants were left standing on the field until November and one or two reached full maturity, and these will be used later in an attempt to grow the plant for hay. There is no doubt at all that the four varieties acclimatized by Mr. North were a great success; two reached maturity on September 1st and two on September 6th. In many cases plants bearing between 300 and 400 seeds were harvested, and some of the finest examples came from the plot which had originally been a vegetable garden with moderate to poor soil.

PLATE 3

English acclimatized soya beans harvested on Fordson Estates, Boreham, Essex, in 1933. *Left to right:* brown 'C', yellow 'J', black 'O', and green 'Jap'. In the foreground is a small sack of Manchurian beans

The influence which change of climate has upon plant growth is very clearly demonstrated in the soya bean. The climate of Manchuria is one of extremes. The intense heat during the growing season suits the plant particularly well, and the sub-soil, which is practically frozen hard during the winter months, supplies all the moisture required by the plant. In some parts sowing is delayed until the end of June, yet the crop reaches full maturity at the normal time. In America, the winter leaves the ground full of moisture and the warmth of the following season is very regular so that growth takes place with a rush. The month of May, in England, is frequently very cold, and it is the slow growth at the beginning that is responsible for late maturity in this country. As part of the 1933 experiment (Essex) small quantities of seed were sown 20 and 10 days before the 1st of May, and although an advance was shown in the early stages it was lost later on, and the plants proved poorer in type and no earlier in the end. It has been found by Mr. North in the course of more than twenty years' study of the subject, mainly with foreign beans grown in various parts of the country, that no variety of soya bean has any chance of success in England unless it matures in less than 100 days in America. Varieties requiring this length of time in America need nearly a month more in this country and, owing to our colder spring weather, no advantage is gained by earlier sowing. Mr. North's seeds require 124 to 127 days to reach maturity in England but, if grown in America, they would only require 85 to 90 days.

THE 1934 EXPERIMENT IN ESSEX

The result of the 1933 experiment was so encouraging that it was determined that a further attempt should be

made in 1934 to ascertain whether it would be possible to grow the plant profitably as a field crop and, with this in view, a field of nearly 20 acres was specially prepared for the acclimatized seeds from the 1933 crop. There was about 10 bushels of seed in all, and the experiment was carried out by the manager of the estate. The four acclimatized varieties comprised a green bean 'Jap', a brown bean 'C', a black bean 'O', and a yellow bean 'J'. Because of the interest which was aroused later when the field was opened to public inspection it is thought that an account of all operations throughout the growing season should be given in full detail.

The field chosen was park land and the soil, light sandy loam. Useful comparisons were made possible during the season by reason of the varied character of the soil, for, although most of the field was good loam, parts were distinctly gravelly where the sub-soil had been raised, and rather more poor than moderate where trees had been felled.

March. The field was tractor-ploughed on the 17th of the month; two days later the field was limed, rolled, and surrounded with wire netting. Nothing further was done until planting time.

May. On the evening of May 2nd the four varieties were spread out in separate groups on a stone floor and inoculated with a culture of active bacteria of the soya bean strain. The culture was well mixed with water and the fluid was washed over the seeds with a broom until the four groups were thoroughly coated with the substance. Sacks were thrown over to keep out the light, and in the early morning of the following day drilling of the seed commenced. An ordinary grain drill, adjusted as

near as possible to requirements, was used for the purpose. The spacing recommended between the rows is 3 feet, but on this occasion only 27 inches could be allowed. The rate of seeding with the drill was just over half a bushel to the acre. In the case of three varieties, 'Jap', 'O', and 'J', sufficient seed to drill was not available, and these were sown by hand with more regular spacing than could be obtained with the drill. One separate row of seeds from a different source, said to be acclimatized, was hand-planted for the purpose of comparison. All seeds were sown in a north to south direction and, finally, the field was rolled.

An inspection on May 15th showed that germination was regular, and that the 'Jap' was three days earlier than the other varieties. The first cultivation took place on May 28th, the hand-hoe being used where horse-hoeing was not possible. A strict watch was kept on birds during this part of the growing stage. Owing to the ravages of birds during this period in 1933 the chance of securing accurate data as to yields in that year was destroyed.

June. On June 15th the height of the four varieties was as follows: 'Jap' 5 inches, 'C' 7 inches, 'O' 6 inches, and 'J' 5 inches. Growth over the whole area was satisfactory and few plants which had germinated had withered.

July. Flowering began on July 4th with the 'Jap' followed by 'C' on the 6th, and 'O' and 'J' on the 10th. By the 14th the plants had reached a height of approximately 10 to 16 inches. The second and last cultivation took place at the end of the month, when the field was horse- and hand-hoed.

The gravelly portions of the field were shown to be too keen for soya bean cultivation; plants on these parts

were stunted in growth and carried sparse foliage, yellow in colour. Plants growing where trees had been felled showed a distinct falling off and many plants had withered on these portions. The appearance of the field in general was considered very good, and there had been no check in growth during the drought. A definite jump forward occurred at the end of the month after rain, and there was a considerable increase in foliage. Although the spacing of the seeds with the drill had not been entirely satisfactory, the close grouping of seed here and there did not appear to have affected the growth of the plants. Actually, plants from drilled seed were slightly in advance of those sown by hand, and it was at first thought that the exceptionally strong growth of foliage would interfere with the normal development of seed and possibly defer maturity.

August. By August 11th the 'Jap' had reached its maximum height of 12 inches, the pods were well grouped and filling out well. The varieties 'C', 'O', and 'J' were 3 or 4 inches short of their full height (24, 30, and 30 inches respectively) and they were podding very satisfactorily. A slight loss was sustained at this period because many plants of the taller varieties had fallen with the weight of pods. In the case of 'C' this was due to a certain extent to irregular spacing with the drill which had frequently allowed 6 to 8 inches, and sometimes more, between the seeds. Soya beans should stand 3 to 4 inches apart so that the plants are close enough to support each other. Later on the branches intertwine and the plants are then able to withstand strong winds. Most of the fallen plants were, however, of the 'J' variety which had been sown by hand, and it appears that this plant has a tendency to fall sideways as soon as the pods begin to fill out. Close

A sturdy specimen of the 'Jap' soya bean plant grown at Boreham, Essex, in 1934. Row-planted with 30-inch spacing, it yielded 15 bushels per acre

planting of seed is, therefore, essential in the case of 'J'. The separate row of plants grown for the purpose of comparison had not started flowering at this date. They were fine, sturdy plants with coarse stalks and heavy foliage, but it was doubted whether they had been grown in England before—certainly they had not been acclimatized.

By August 24th the pods on all varieties were filling out well and the 'Jap', still a few days in advance, was changing colour. The leaves were turning yellow and were shrivelled in appearance, and the pods were turning brown. The variety 'C' had reached a height of 22 inches, 'O' 27 inches, and 'J' 27 inches. The 'J' variety appeared to be less advanced at this date than was the case in 1933.

September. An inspection on September 1st found that very few leaves remained on the 'Jap', most of the pods had turned brown and a general crispness had set in. Change of colour was taking place in the 'C' and 'O' varieties, but 'J' was a little behind. All had attained full height. By September 4th the 'Jap' had reached full maturity; the plants were quite leafless and the pods dark-brown. The seeds were unflecked and true to type. Most of the leaves of 'C' had fallen and the pods were changing colour rapidly. The 'J' variety always keeps its leaves late into the season, and at this date they were just beginning to change colour. Recent rain had caused new leaves to appear on 'J'.

It was considered that if the 'Jap' plants were left standing longer in the field the pods might shatter, so they were cut on September 5th and left on the field in piles to dry thoroughly before threshing. The plants of the 'C' variety were also ripening well, and these were

being cut and left on the field as they reached maturity. It was thought that a few more days would bring the 'O' plants to maturity. The 'J' variety was still a little behind.

An interesting conclusion was reached after a careful inspection of the field. Plants growing on the borders where the soil was distinctly thin had reached maturity before the rest of the crop. Plants of the 'C' variety, for instance, which had not quite reached maturity in the good loam in the centre of the field were ready to cut on these spots. The poorer types of soil were shown to suit the bean better than rich soil. That rich soil apparently weakened the plant's resistance to frost was shown in the case of a group of plants growing on a part of the field where a tree, surrounded by a cow-crib, had originally stood. Examination showed an abnormal growth of foliage still green and tender; the well-developed pods were still in the green stage, and the outer row of plants were blackened and shrivelled by the light frosts of late August. By September 10th all the 'C' plants had been cut and piled in the field. Many of the 'O' plants had reached maturity, but not all: those which had ripened were cut. The 'J' variety at this date was ripening very irregularly, but the pods were well filled and change of colour was taking place slowly. A considerable amount of rain fell during the first half of September, and its effect was shown in deferred maturity in the case of 'J'.

A certain amount of disappointment was felt that this variety had ripened so unevenly, and later than was the case last year. In 1933 'J' seeds sown on May 1st matured on September 6th and they ripened regularly. It is difficult to give a reason for the change: wet weather towards the end of the season, too rich a soil, or three days later sowing may each have had an influence in deferring

The 'J' variety produces straw-yellow seeds which are valuable for both protein and oil. There were more than 140 pods on this plant when harvested (Yield, 18 bushels per acre)

Method of sowing adopted in 1934 experiment

Variety of seed	*Green* '*Jap*'	*Brown* '*C*'	*Black* '*O*'	*Yellow* '*J*'
Date of sowing	May 3	May 3	May 3	May 3
Method of sowing	By hand	Drilled	By hand	By hand
Rate of seeding (p.a.)	25–30 lb.	37 lb.	25–30 lb.	25–30 lb.
Space between rows	30 in.	27 in.	30 in.	30 in.
Space between seed	3–4 in.	3–4 in.	3–4 in.	3–4 in.
Depth of sowing	$1\frac{1}{2}$–2 in.	$1\frac{1}{2}$–2 in.	$1\frac{1}{2}$–2 in.	$1\frac{1}{2}$–2 in.

Behaviour of plants during 1934 experiment

	'*Jap*'	'*C*'	'*O*'	'*J*'
Germination	May 12/15	May 12/15	May 12/15	May 12/15
Flowering	July 4	July 6	July 10	July 10
Height at June 15	5 in.	7 in.	6 in.	5 in.
Height at July 14	10 in.	17 in.	15 in.	16 in.
Height at August 11	12 in.	21 in.	25 in.	26 in.
Height at Sept. 1	12 in.	24 in.	30 in.	30 in.
Date of maturity	Sept. 4	Sept. 6/10	Sept. 10/15	Sept. 20/27

Analyses of the soils from the soya bean field

Samples analysed	*Nitrogen*	*Chalk*	*Available potash*	*Available phosphoric acid*
Outer edges of field .	0·207	0·07	0·018	0·022
Tree holes originally surrounded by cattle cribs . .	0·423	0·16	0·064	0·085
Centre of field (loam)	0·231	0·08	0·021	0·021

This photograph shows the 'O' variety (for hay) at the seed stage. This plant, row-planted for seed, attained a height of 30 inches. Close drilling for hay would tend to increased height. It is many-stemmed and carries good foliage (Yield, 15 bushels per acre)

The analyses show little difference between the soil from the 'outer edge of field' and that from the 'centre of field', but plants growing on the former reached maturity before those in the latter. The soil from 'tree holes originally surrounded by cattle cribs' is shown to be particularly rich in nitrogen, which accounts for the abnormal growth of foliage, the well-developed pods still in the green stage at the end of the season, and the susceptibility to frost.

It has been stated that the soya bean will grow well in acid soil if lime is applied, and this proved to be the case as shown by a report on the general condition of the field: 'The soil was markedly acid when brought under cultivation but, notwithstanding the fact that lime was applied during preparation, it was found to be definitely low in chalk and required further liming in the near future.'

DESCRIPTION OF THE FOUR VARIETIES

(1) The 'Jap' bean is particularly suitable for use as a green vegetable because of the extraordinary amount of protein contained in it; there is nothing to equal it in either the animal or vegetable kingdom. That its oil content is low matters little, for, in food value, the protein is always of the greatest importance. The plant, which is of dwarf-growth with a maximum height of 12 inches, is very densely podded and somewhat bunched in appearance, and it requires 124 days to reach maturity in England. The beans are pale-green in colour and number 2,644 to the pound. In size they are similar to the ordinary green pea but flatter in shape. The 'Jap' is Mr. North's newest variety and it reaches maturity several days earlier than the others.

(2) The 'C' variety produces a dark-brown bean

slightly smaller in size than the 'Jap' but heavier in weight as is shown by the number of seeds to the pound which is about 2,442. The plant has a spreading habit of growth and carries its pods well; it reaches a height of 24 inches. The 'C' variety requires about 127 days to reach maturity in this country, and has been grown experimentally in England for the last thirteen years proving itself to be a very reliable podder.

(3) The 'O' variety is a forage seed. Row-planted for seed purposes in 1934, it attained a height of 30 inches; drilled for hay the tendency would be for increased height. The plant is of the fine-stemmed type with good foliage and small, thin pods. The beans are black, small, flat and rather more oval than round, and they number 3,490 to the pound.

(4) The 'J' variety produces the largest seeds of the four types and they are straw-yellow in colour. They number 2,070 to the pound. The plant is of the upright, spreading type, and as it has a tendency to fall with the heavy weight of pods should be planted closely, i.e. the spacing between the seeds should be regular and not more than 3 to 4 inches apart. The 'J' requires about 127 days to reach maturity in this country in a dry season. In 1934, the plants of this variety took fourteen days longer to mature owing to wet weather towards the end of the season. The seeds were of exceptional quality and have been stated to be distinctly superior to Manchurian beans. The plant keeps its leaves very late into the season and attains a height of 30 inches.

The following Table gives the composition of the four varieties described above (analyses 1933 and 1934) together with that of four common varieties grown in America, and the typical Manchurian bean for the pur-

pose of comparison. English beans are shown to be higher in protein and lower in oil than the American varieties, whilst the Manchurian bean stands midway between the two both in protein and oil.

Composition of English and other varieties

	Protein	*Oil*	*Water*	*Ash*	*Carbo-hydrates*	*Crude fibre*
English	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
'Jap' (1933)	46·26	13·00	8·32	4·97	22·89	4·56
,, (1934)	46·63	12·47	7·92	5·00	23·98	4·00
'C' (1933)	40·92	15·40	8·67	5·30	25·63	4·08
,, (1934)	41·64	15·15	8·04	4·70	25·97	4·50
'O' (1933)	40·09	16·96	7·89	5·15	24·57	5·34
,, (1934)	43·07	15·64	8·04	4·75	23·25	5·25
'J' (1933)	36·90	16·80	7·26	5·20	29·09	4·75
,, (1934)	37·66	15·95	8·09	5·03	28·90	4·37
U.S.A.						
Ito San .	34·66	19·19	7·42	5·97	27·61	5·15
Midwest .	35·54	19·78	8·00	5·85	26·30	4·53
Mammoth .	32·99	21·03	7·49	5·01	29·36	.4·12
Quelph .	33·96	22·72	7·43	5·85	25·47	4·57
Manchurian						
Typical .	36·68	17·50	12·00	4·92	24·10	4·80

It will be seen from the above Table that, in 1934, each of the four varieties showed an increase in protein and a decrease in oil as compared with the same varieties grown in the same part of Essex in 1933. The analysis of the brown 'C' seeds for 1933 showed an increase of 0·74 per cent. in oil over the same variety grown elsewhere in 1927, and in yellow 'J' there was a progressive movement of 1·12 per cent. in oil over the same variety grown in 1932. Does locality affect the quantity of oil in the bean as it does the yield? The 'J' seeds of 1932 were harvested

in the Thames Valley, west of London, and it is possible that the change of environment, or situation, to warm, dry Essex may have been responsible for the increase. A glance at the Table, however, shows that the increase in 1933 was not maintained in the seeds of 1934 grown in Essex. What was the factor responsible for lowering the oil content in 1934 when the seeds were grown for the second time in the same locality ? The use of lime, which is known to increase protein rather than oil, may have had some bearing on the matter. The field under soya cultivation in 1934 received a fairly heavy application of lime in March of that year. The results shown in analysis for the years 1933 and 1934 are very interesting, but they raise questions which cannot be answered satisfactorily until further experiments have taken place. That certain constituents used in fertilizers are effective in raising oil content is shown by the analyses (p. 43) of seeds taken from fertilized plots when compared with those from plots not receiving fertilizer.

A view of the soya bean field as it appeared on August 29th, 1934. This was the first time soya beans had been grown in England as a field crop. Several tons of seed were harvested by Fordson Estates in the middle of September

IV

THE CULTURE OF THE SOYA BEAN

THE soya bean plant is adapted to a wide range of variation in climate although it flourishes best in temperate regions with fairly humid, warm summers. In the country of its origin it grows up to the 52nd degree of northern latitude, but the region most suited to it is about the 44th degree. In the United States it grows successfully in soil suitable for maize up to the 47th degree. The southern parts of England lie between the degrees 50 and 52, but owing to the influence of the Gulf Stream we enjoy climate 20 to 25 degrees warmer than our latitude suggests instead of one as cold as that of Labrador. The southern, eastern, and midland counties of England appear to be most suited to the cultivation of the soya bean. The best sunshine records are usually in the south. In the north there is not sufficient sunshine, whilst in the west there is too much moisture for early maturing, and the plant germinates and grows very slowly in cold, wet soils. The south-eastern section of Essex is the driest district in England, and is reputed to be subject to long periods of drought in the spring and summer. The weather report of September 8th, 1934, gave Essex as the warmest place in England, with a temperature of 83 degrees in the shade.

The determination of the best variety for a given region is not an easy task. In choosing a variety capable of withstanding the vagaries of the English climate such factors as habit of growth, ability to retain leaves, colour and size of seed, the tendency to shatter pods, and the yield have

each been studied. Types of soil as well as the position of the field are equally important and should come under consideration in attempting to cultivate the plant. It is for the prospective grower to study the position of his land with a view to weather conditions and suitability of soil, to cultivate the plants with care and, from personal experience, gain a knowledge of the plant's habits and requirements. It will be found that varieties growing under proper cultivation will, like other cereal crops, produce seeds of larger size and better quality than the same variety left to struggle with weeds. Weather conditions will affect the size of the seed—a type requiring all the season to mature will produce heavier seeds when the last month is favourable for ripening than when cool weather sets in towards the period of maturity. Row-planting coarsens the stems, whilst drilling closely for hay has the reverse effect. Fertile soils will produce coarser stems and heavier foliage than moderate to poor soils. Rich soil weakens the resistance of the plant to frost.

As the greater number of the failures which have attended early attempts to grow soya in England have been due, to a large extent, to want of knowledge of its habits and requirements, and in view of the fact that inquiries as to the manner of growing it have been made from time to time by farmers in various parts of the country, an account of the manner of handling the crop is given.

Soil requirements. It is perfectly clear that a rich soil is wasted on the soya bean. A light loamy soil suits it best. In soils of a medium texture it grows remarkably well, and it succeeds in poor soils provided all other conditions for its normal development are favourable. These conditions include as much sunshine as possible, an open situa-

Soya beans inoculated the previous day being fed into the drill preparatory to sowing. Dull days are best for sowing infected seed as sunlight is unfavourable to bacteria. The seeds were sown in the early morning, therefore, and the drill was covered to keep them shaded

tion, fairly good drainage, freedom from weeds, and the proper inoculation of the seed. Soya beans have made a satisfactory growth in soil of very low fertility when nitrogen-fixing bacteria were present; in acid soil when lime was used, and in very poor soil when the mineral elements lacking were made good. Good results have been obtained in the very wide range of soils found in Europe, but the best results abroad have always been obtained in soils of a medium texture, and in sandy and clay loams containing lime, phosphates, and potash. Soils deficient in lime should receive attention before a crop of soya is contemplated, and the winter dressing should be applied early if it is to be fully effective on the soya crop to be sown in May. Lime helps to increase the yield and is of further use in freeing the reserves of potash locked in the soil. Like all bean plants, soya can do with all the potash it can get.

The plant is drought-resistant and able to keep alive during the driest weather. Also, it is not particularly sensitive to excess of moisture of which it seems to take advantage later on, but it must not be expected to succeed in soils which are water-logged for any length of time. Light frosts have little effect on the young plants, or even when they are nearing maturity, and if the pods are fairly well-developed before heavy frosts occur the plants usually ripen satisfactorily.

Inoculation of the seed. Nitrogen is one of the ten essential constituents of plant food. The supply in most soils is often limited although it is required in large quantities. It is usually one of the first fertilizing elements to be depleted in the soil, and certainly one of the most expensive to restore. By means of leguminous crops grown in association with nitrogen-fixing bacteria, large quantities

of free nitrogen from the atmosphere may be added to the soil at small cost and with very little trouble. It is a well-known fact that the roots of leguminous plants attract certain bacteria existing in the soil which penetrate by the root-hairs and form enlargements, called nodules, on the roots. Such bacteria, living within the nodules attached to the roots of the plants, are able to draw in from the air large quantities of free nitrogen and convert it into nitrates for the use of the plant. Amounts far in excess of the needs of the plants are gathered so that the store of combined nitrogen in the soil is materially increased. It is also a fact, not quite so well known, that leguminous crops instead of improving the soil in which they are grown may actually exhaust it if nodule bacteria are not present, because the plants will be obliged to draw their nitrogen from the existing store in the soil. Many farmers help to keep up the supply of organic matter in their soils by growing the lupine. Pulled at almost any stage of growth the roots of this plant show nodules, and it is through the agency of the bacteria which have formed, and live in, these nodules that soil improvement is brought about. Much of the work carried on by these micro-organisms is not clearly understood. Why they should have such a peculiar chemical influence on leguminous plants is a mystery; all that is known is that Leguminosae are, by this means, able to add nitrogen to the soil when the root-hairs have become infected with *the right strain of bacteria*, and this is what inoculation accomplishes in the case of the soya bean.

It happens that the particular strain of bacteria required by the soya bean is not present in English soil; neither was it present in the soil of the United States until it was introduced into it. The living organisms which

produce nodules on the roots of other legumes are not suited to this bean, and bacteria from the nodules of other legumes will not inoculate it. Soya bean bacteria must, in the first instance, be introduced artificially into English soil, and it is done by dressing or inoculating the seed before it is sown. This does not mean that the soya bean will not grow here without inoculation—it will, but the beans will not be so large and heavy in weight as would be the case had the treatment been given. Also, the plants will draw their supply of nitrogen from the soil instead of being the means by which the supply is increased. In the experiments conducted in Essex, bacteria was introduced (in 1933) by means of infected soil in which soya beans had been grown for several years, and (in 1934) by culture obtained from abroad. The prospective grower will naturally ask how he shall inoculate his seed when the necessary culture is only obtainable at considerable expense from abroad, and when infected soil is not readily available. It is a fact that, at present, he cannot do so, but it is probable that when seed is ready for sale he will, in the first year, be able to purchase seeds already treated if required. The probability is that as soon as large stocks of seed are available, and the crop is on the way to establishment in this country, cultures would soon be made for the purpose.

When nodules in abundance have been found on the roots of soya beans, soil from that field may be used for the further inoculation of other fields in the same vicinity. Under suitable conditions of growth nodules should develop provided the necessary bacteria are present in the soil or have been supplied by direct inoculation of the seed. A few nodules were found on the larger plants grown in Essex in 1933 and 1934, but they were confined to the main root. The growing seasons during both years

were exceptionally dry and therefore favourable to soya bean cultivation, but they were not good years for the formation of nodules. There was very little rain, and moisture is required for the proper infusion of bacteria through the soil. Acclimatized beans were grown successfully by the writer in a London garden in 1933, and although the seeds were inoculated no nodules were found on the roots. The seeds from this 'crop' were inoculated and sown in the same spot in 1934. It happened that an undiscovered leakage of water through the area where the beans were growing had been flowing for more than a month, and the soil had become very damp. The leakage was repaired in early August, and when the plants were uprooted at the beginning of September all four varieties carried nodules, about the size of peppercorns, in groups at the base of the main roots with smaller ones extending to the lower roots. Nodules do not usually appear in abundance on soya until the second or third year, and then only if the seeds are inoculated and grown in the same soil.

Where the plant is grown extensively the organism becomes established and, once infused through the soil, natural inoculation occurs. This has taken place to a large extent in America, and the need for dressing the seed before sowing is now only required when quite new areas are being brought under soya bean cultivation.

Nitrogen-fixing bacteria supply nitrogen only; they do not supply, or increase, other plant elements. If the soil is to derive the greatest benefit from the growth of legumes, and in particular soya, phosphates, potash, and lime should not be allowed to become deficient. Given these constituents they will grow in such unlikely mediums as sand, or even cinders, and symbiotic bacteria render available much more atmospheric nitrogen than

Under nearly all conditions soya beans should be sown in rows sufficiently wide to allow for cultivation later on. The ordinary grain-drill, adjusted to requirements, was used for the purpose

is required by the plants. The value of bacteria in connexion with leguminous plants where soil conditions are favourable is obvious, and growers, especially those cultivating soya for the first time, will find consideration of the subject well worth while. The value of inoculation does not end with its influence in improving the soil, nor upon the yields of following crops of other kinds grown in the same soil, a benefit is at once obtained in a better quality bean, heavier in weight and having a higher percentage of protein content. Analyses of seeds from inoculated plants have shown 42·47 per cent. protein as compared with 35·26 per cent. in seeds from plants not so treated. Several writers state definitely that inoculation of the seed always increases the yield, the difference being shown, not in an increased quantity of beans over the amount normally produced, but in larger, heavier beans. The very sturdy plants harvested in Essex in 1933 carried well-developed pods filled with larger seed than those sown, and this was considered by Mr. North to be largely due to good inoculation. The Essex experiments were the first of the kind to be conducted on a fairly large scale in this country, and it is perhaps necessary to form an opinion from experiments taking place over a number of years—a great deal of importance is, however, attached to inoculation in America where, it is stated, a difference of $2\frac{1}{2}$ tons green weight results to the acre.

A few details concerning the various methods used in inoculating the soya bean may be found useful. Many growers will, no doubt, prefer to dress their own seeds when sowing fresh plots. The culture used in 1934 took the form of fine black powder. Apparently it had been made first in liquid form and allowed to soak into charcoal and dry, afterwards being ground to powder. A

description of the method used in this case has already been given. Mr. North inoculates his seed with infected soil. He has his own soya bean plot where the plant has been growing for many years and the soil from it is, therefore, well infected with nodule bacteria of the required strain. The soil is dried and pulverized until it is fine dust. A small quantity of sticky solution is dissolved in water and the liquid is sprinkled over the seeds. Only sufficient moisture to hold the dust is required. The dry, infected dust is then sifted over the dampened seed and the whole mass is stirred gently so that the bacteria adheres. A pound of infected soil is sufficient to inoculate a bushel of seed. Soya beans should be sown as soon as possible after treatment, and a dull day is best for the task as direct sunlight is unfavourable to bacteria. This method, if properly carried out, is effective in putting bacteria on every seed. Large quantities of seed may be dealt with by pouring mud-thickened, infected soil over them and stirring. Seeds so treated should always be dried before being sown. Another method is to transfer to the field being sown, soil from another field where soya beans have been grown previously and where the roots have been known to carry nodules. Dry, sifted, and infected soil has been mixed with the seed and sown with the drill, but the results have not proved satisfactory, for inoculation is not sure.

Preparation of the soil. There is probably no crop that responds more readily to good soil preparation than the soya bean, nor one that can fail more completely for lack of it. It calls for less attention than most crops once growth is established, and ordinary farm equipment suffices for all its requirements. The crop should be started with a good seed-bed. Sown in poorly prepared

soil twice as much attention will be needed later on, and the crop cannot be expected to give good returns if the land is weedy. The seed-bed should be fairly compact underneath without being hard, and the surface soil for 2 or 3 inches down ought to be light and loose. Light, medium, and sandy types of soil should be ploughed and left until a week before planting, limed if necessary, and rolled. The more heavy types of soil usually require breaking up in the autumn to allow the weather to take effect. A final rolling down after the seeds are in helps to give a uniform depth to planting. If the crop is sown over a large area, good levelling of the land is essential so that the grain-binder may move easily over the ground in harvesting the low-growing plants. Tussocks of grass on the field not only delay the machine, they are the cause of many a plant being cut in half, and of whole rows left uncut. If the land is kept clean throughout the growing season, and scuffled when the beans are off, a good seed-bed for winter wheat is furnished without further preparation.

Weeds are the worst enemy of the soya bean which, like other young plants, is quickly choked out of existence by them. The crop is easily ruined in the early stage, when growth is slow, if weeds are allowed to predominate. They should be kept down vigorously. Weeds absorb the water and food belonging to the plant; they harbour disease, of which the soya bean is singularly free at present, and they stop sunshine and encourage pests.

Rates of seeding. The quantity of seed required to the acre will vary according to the purpose for which the crop is grown, to the variety of seed used, and the space allowed between rows and plants. The number of seeds to a bushel ranges from 75,000 in some varieties to

600,000 in others. The English acclimatized varieties range from 124,000 per bushel in the 'J' to 209,000 per bushel in the 'O'. In Essex (1934) half a bushel of seed per acre was used for 30-inch row-planting, and 37–40 lb. for drilling in 27-inch rows. The amounts used in various countries are as follows:

Rates of seeding in various countries

COUNTRIES	*Row-planted for seed* (p.a.)	*Drilled for hay* (p.a.)
United States . .	20–35 lb.	60–90 lb.
Canada	30–40 „	60–120 lb.
Japan	36–40 „	. .
Manchuria (Interior) .	20–30 „	. .
River Valley regions .	10–15 „	. .

Sowing the seed. The proper time for sowing the soya bean is the first week in May, and if possible on the 1st of May. In England, harvesting must take place in early September, and only 19 to 20 weeks can be allowed for the plant to reach maturity. Earlier sowing is of no advantage. Late planted seeds fail to reach maturity. The seeds should be sown with the pea- or bean-drill adjusted to requirements to prevent cracking of the seed in larger varieties. Under nearly all conditions the bean should be row-planted for seed, and drilled closely for hay. In the East, where the sunshine is intense, the seeds are sown from 5 to 7 to the foot in rows about 20 to 27 inches wide, but in countries like England, where the heat of the sun is far from extreme, wider spacing should be allowed between the rows, particularly in the cases of the taller varieties such as 'C' and 'J'. A spacing of 30 inches was allowed (1934) in the case of the 'Jap' which is of dwarf-growth, but it is now considered that

ll quantities of different varieties of soya bean being sown by hand in 30-inch rows

half this amount would have sufficed, for this variety loses its leaves early and is of the small bunched type. If English summers were always as dry as those of the last two years, closer planting would be possible for all varieties grown for seed, but heavy rain through the growing season makes for a considerably heavier growth of foliage and in a wet season row-cultivation, and even a free passage down the rows, may be made impossible.

The depth of sowing is $1\frac{1}{2}$ to 2 inches, and 3 to 4 inches should be allowed between each seed. The mistake of planting too deep is to be avoided for the germinating seed uncurls and lacks the boring force to push upward through deep layers of soil. On the other hand, surface planting (less than $1\frac{1}{2}$ inches deep) results in poor stands, and, as the root is given to spreading under the surface soil rather than to penetrating downwards, the plants fall with their own weight as soon as the pods begin to fill out. Two inches proved successful in Essex and germination was regular. By sowing in a north to south direction the maximum amount of sunshine is obtained.

The ideal way is to plant by hand allowing from 2 to 4 inches between the plants and 40 inches between the rows. Sown in this way from 15 to 18 lb. of seed per acre is all that is required. Hand-planting is not practicable where sowing is to be carried out on a large scale, but on the small plot where the seed is being tried out for the first time this method is, undoubtedly, the best.

Cultivation. As soon as the plants are through one good cultivation should be given, and light hoeing as required should be sufficient to keep weeds down until blossoming time, after which cultivation should cease. Hoeing is best applied during the heat of the day when

the plants are dry. If crusts form after heavy rain in certain types of soil very light harrowing may be found necessary to help the young plants through. Except for keeping down weeds very little work is required after the flowering period, and it is at this stage that rabbits should be watched for. Where rabbits are numerous soya bean culture is made practically impossible. Wire-netting keeps them out, and if set low enough keeps them from burrowing under. Birds also do an enormous amount of damage when the seed-leaves of the plant appear above ground. Wired-in fruit areas could be utilized quite well for the soya bean crop. The seeds could be sown between the young trees, and the wire-netting would serve the dual purpose of keeping cattle and rabbits away.

Fertilizers. Although the acclimatized soya bean will grow in most soils without direct application of fertilizers, their use is recommended when the crop is being started in soil of low fertility. The plant is a heavy user of nitrogen, phosphates and potash, and soils poor in these substances need special attention. Commercial fertilizers on good land do not show marked results over the good yields of beans produced normally, and experimental tests conducted over a number of years have shown that very little difference appears between plants taken from good soil receiving fertilizer, and those from soil equally good but not receiving fertilizer. Acid soils showed a distinct increase in yield when lime was applied. Lime has an influence on nodulation which, in its turn, influences the nitrogen supply added to the soil; it is, in fact, as important as inoculation, although the one should not be allowed to take the place of the other. The roots of plants from limed plots show twice as many nodules as

PLATE 11

A final roll when the seeds are in helps to give an even growth and better stand to the plants

those from unlimed plots, whilst the reverse is the case in unlimed plots even where bacteria were plentiful in the soil. The conclusions reached after a series of tests carried out in the United States over several years to gauge the effect of nitrogenous and mineral fertilizers upon yields, found that the former had little effect upon yields or upon the percentage of protein contained in the bean. Special experiments were carried out in studying the effect of nitrogenous fertilizers upon the percentage and amount of protein in the crop. The results indicated that 'while mineral fertilizers are of great value in increasing production, nitrogenous fertilizers do not greatly increase the yield or percentage of protein in the crop over that obtained from the mineral fertilizers only. The percentage and yield of protein in the soya bean bear little relation to the quantities of nitrogen used'. Mineral fertilizers were found to be of considerable value for increasing production. High-grade sulphate of potash increased the yield more than the muriate; elementary sulphur stimulated plant growth to a certain extent, and an increase in yield and protein content was shown. Lime increased the yield and the nitrogen content of both plant and seed. Basic slag and superphosphate were equal in their effect upon yields; the choice between superphosphate and slag was, therefore, determined by the amount of lime present in the soil. Superphosphate and high-grade sulphate (or muriate) of potash has been recommended, and if potash manures are not available, wood ash. Wood ash was thought by some to be superior to other potash manures.

Certain special fertilizers were used in the Essex (1934) experiment. The mixtures were private blendings and balances, the raw materials from which they were compounded being derived from different sources chiefly

from an organic base. The land on which the 1934 crop was grown had been ploughed up from turf and was, therefore, fairly rich in nitrogen. The growing season was very dry and there was very little rain from the time of sowing. The difference in fertilized plants compared with those not receiving fertilizer was not marked, but the results were instructive if not conclusive. Four plots, planted with the brown 'C' variety of bean, were treated with different artificial manures supplied by a well-known firm of agricultural chemists; the manures contained the following constituents:

Plots	*A*			*D*
	per cent.	per cent.	per cent.	per cent.
Phosphates	24	16½	23½	13
Ammonia	2		1	9
Potash .				4

Of the four plots the plants in *C*, which had been treated with fertilizer derived mainly from a mineral source containing a high percentage of phosphates (20 per cent. soluble in water and 1½ per cent. soluble in citric acid), and 6 per cent. of pure potash, appeared to have given the best result. The plants in *A*, treated with fertilizer containing a large proportion of organic raw materials, and *B* were healthy and well-developed, but not more so than those in untreated plots. An inspection of *D* showed that extra nitrogen was, apparently, not required, for the plants appeared to be over-forced, and there was leaf-curl and a shrivelled appearance in the green leaves throughout the growing season. A fifth plot *E*, adjacent to those mentioned above, received pure fertilizer at the rate of two parts each superphosphate and sulphate of potash to one part ammonia. The plants in this plot were also, apparently, overforced, there was leaf-curl and, as in the case of *D*, maturity was slightly

deferred. A great deal of difference was not shown in the growing plants, but the following Table is of exceptional interest in showing the change in content of the bean brought about by the effect of different blendings of fertilizer. The 1934 analysis of the brown 'C' variety is repeated for the better comparison with seeds of the same variety taken from the five fertilized plots. A double check was taken of the seeds from plot *D* the protein content of which, it will be noted, was nearly three points higher than those which had not received fertilizer.

Analyses of seeds taken from fertilized plots

Content, per cent.	*1934*	*A*	*B*	*C*	*D*	*E*
Oil . . .	15·15	14·94	15·35	15·12	14·60	15·36
Protein . .	41·64	41·86	41·81	41·23	44·44	41·65
Moisture . .	8·04	8·10	7·70	8·18	8·18	8·08
Ash . . .	4·70	4·59	4·37	4·81	4 09	3·90
Crude fibre .	4·50	4·16	4·16	4·42	3·86	4·18
Carbohydrates (by difference) .	25·97	26·35	26·61	26·24	24·83	26·84

NOTE:

Plot *A*: 0·21 per cent. decrease in oil.
0·22 per cent. increase in protein.
Plot *B*: 0·20 per cent. increase in oil.
0·17 per cent. increase in protein.
Plot *C*: 0·03 per cent. decrease in oil.
0·41 per cent. decrease in protein.
Plot *D*: 0.55 per cent. decrease in oil.
2·80 per cent. increase in protein.
Plot *E*: 0·21 per cent. increase in oil.
0·01 per cent. increase in protein.

The straw obtained after threshing the bean has its fertilizing value; it contains more nitrogen than the straws of wheat, oats, or barley. In some parts of the

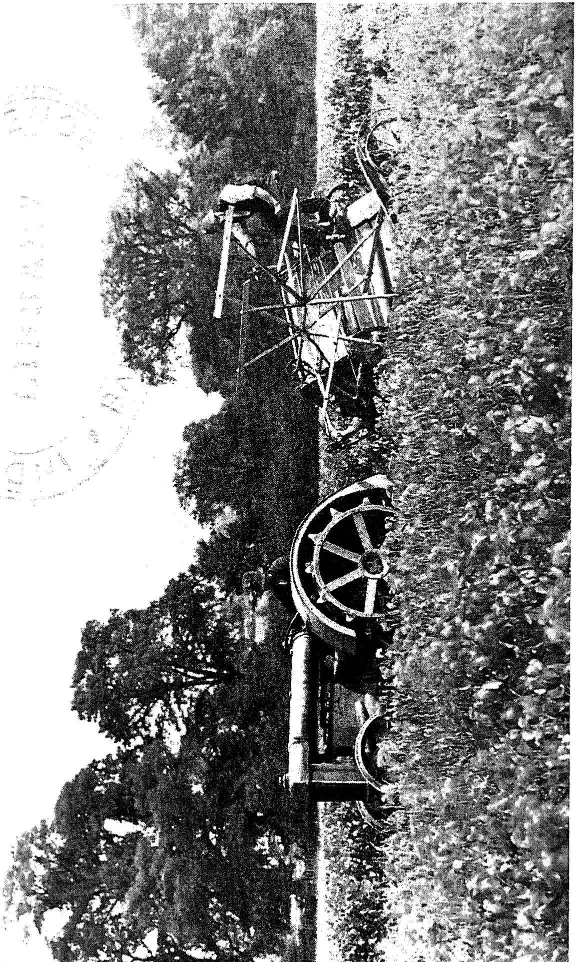
United States, where the bean is grown for seed purposes, the straw is thrown out at the time of threshing and spread ready for turning under. Its fertilizing value, obviously, is greater when returned in the form of manure. The following Table is reprinted from *The Soybean* and gives the fertilizing constituents (1,000 lb.) of soya bean straw as compared with that of wheat, oats, barley, and rye.

Fertilizing constituents of soya and other straws
(1,000 lb.)

Straws	*Nitrogen*	*Phosphoric acid*	*Potash*
	per cent.	per cent.	per cent.
Soya . .	9·0	1·2	8·9
Wheat . .	5·0	1·3	7·4
Oats . .	5·8	2·1	15·0
Barley . .	5·6	1·8	12·0
Rye . .	4·8	2·8	7·9

The fertilizing value of soya cake is high but, up to the present, it has only been used for this purpose in the East. Ammonia, potash, and nitrogen are present in soya meal, and manufacturers of fertilizers in the United States purchase considerable quantities for this purpose. Soya bean meal is very rich in plant food constituents, and valued on the same price basis as cotton-seed meal used for fertilizers is considered a more valuable substance.

Harvesting the crop. When the leaves begin to turn yellow and fall, the time for harvesting is approaching. The plants should be allowed to stand in the field until all leaves have fallen and the pods have turned colour. Some foreign varieties tend to shatter their pods if left standing too long after reaching full maturity. As soon as the



Harvesting soya beans with the reaper and binder

pods show signs of splitting the plants should be harvested without delay, otherwise the inexperienced grower will suffer considerable loss in seed. Fortunately, the English acclimatized varieties have not this tendency to shatter the pods and they may be safely left standing in the field until the beans rattle in the pod. Attempts are sometimes made by new growers to harvest the soya bean crop before it is ripe with a view to obtaining hay and seed at the same time. Hay should, however, be cut three weeks to a month before the beans are ready to harvest, and there is no period when the crop can be cut to produce good hay and seed at the same time.

The tendency with the small crop is to pull the plants rather than cut them, because, being short and shallow-rooted, it is so much easier to do so. It is poor economy where the soya bean is concerned, for the roots are of no value whatever out of the ground and of much value in it; they should be left with all the other debris of the crop to benefit the soil. In the Orient the plants are more frequently pulled than cut because the Manchurian farmer has a use for them as fuel. He has no thought for the future in thus depriving the soil of the provision made for it by Nature, and as a consequence, the soil of south-west Manchuria, where soya bean culture has been carried on for centuries, is said to have become so poor in organic matter that it no longer bears the rich harvests of the past.

Small areas may be cut with the sickle or reaping-hook, but where large areas are being dealt with the reaper-and-binder is used. An attempt was made to harvest the crop in Essex (1934) with the reaper-and-binder, but the ground was much too uneven so that the plants were cut in the middle instead of at the root. All sorts of cutting implements were tried in this experiment

in order to find the best and quickest method, but the plants were too tough and, eventually, the sickle was used and found to be quite successful.

After cutting, the plants should be left in small piles to dry out thoroughly in the field. Turning over is necessary so that the plants underneath may dry. Drying of the seed is quite important, and the pods should be very brittle before threshing takes place. If moulding is to be avoided after rains the piles should be turned occasionally, and if it is impossible to dry on the field the piles should be removed to a dry barn with good ventilation. It was found in Essex (1933) that dried plants stacked in a barn to await threshing became unfit for the purpose after a few days. The moist atmosphere of early autumn dampened the pods, and, although the seeds inside were perfectly dry, threshing could not take place and extra labour was entailed in continual turning over before the seed could be dealt with. Threshing should not be delayed longer than absolutely necessary when once the pods have dried. Rats and mice are fond of the soya bean, and these pests do an enormous amount of damage in twenty-four hours. Apart from the amount they eat, they have the objectionable habit of nipping the seed and leaving it, thus destroying the germinating power.

The initial cost of soya seed will, for a few years at least, be high because so little will be available in this country. It should, therefore, be borne in mind throughout the cultivation of the crop that every seed is valuable, perhaps more so than any other grain, and every effort should be made to save them all. The foregoing remark may appear to be redundant but, actually, an enormous amount of waste can occur with this crop. A dozen plants carrying two to three hundred seeds or more trampled under here and there; a few plants lost during harvesting

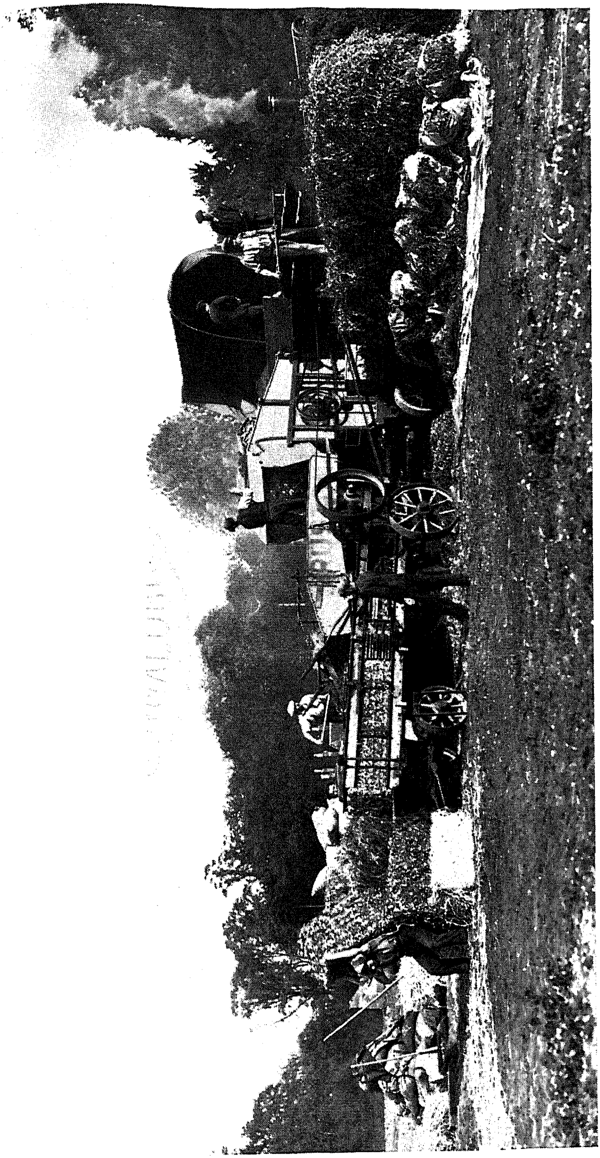
and threshing; loss due to bad storage (the last men tioned item is so easy with oil-bearing seeds) help to mak a considerable difference in weight of yield. If left to long in the field the pods burst and many seeds are lost These are some of the reasons why accurate data as t yields was not available after the 1933 experiment i Essex. Experience in the cultivation of the soya bean i yet very limited in this country and a word in time i of great value.

Threshing. The soya bean is threshed with the ordin ary grain-threshing tackle. In good drying weather th plants may be threshed on the field. The small crop o 1933 was flailed, but this method is not entirely satis factory with soya beans. Threshing tables consisting o rough boards made with 2-inch slats placed 2 inche apart are used in many parts of the United States wher small quantities are being dealt with. Placed on canva on the field between the piles of cut plants 50 to 75 bushel can be beaten out in one day if two men carry the bundle and two beat for the seed. Where the bean is harvested on a very large scale, bean harvesters are used, and two men clear an acre in two hours. A certain amount of seed is sacrificed, but this is compensated for by the saving of time and labour. The bean harvester does all the work in one operation. It passes down the rows of standing plants, cuts, threshes, and cleans; a man rakes the seed to the rear of the machine, where it is delivered into sacks which are then tied and dropped off for later collection. Broken stems and empty pods are cleared out in the process and left on the field with the vines for ploughing in later. The Essex crop of 1934 was threshed on the field with the 'Ruston' Thresher. A very large quantity of straw was baled at the time of threshing, and there was a siderable quantity of tail or split beans thrown out of

the machine, and spent pods torn from the plants when threshed. The feeding value of the spent pods should be greater than that of the straw, which is rather coarse and woody in character. Certain quantities are to be offered to those farmers who would care to use it in experiment and report on the result.

Storage. Moisture content is always a factor to be considered in the safe storage of oil-bearing seeds, but if care is exercised they can be stored for long periods without loss. Soya beans should not be stored in deep bins, or more or less air-tight sacks. Such massing together of large quantities is to be avoided as the sweat stage cannot be passed without heating, and heating quickly reduces the power of germination. Sacks of soya beans for transport should be tied in such a way that the beans are loose in the sacks. The final drying out of oil-seeds is very important, for upon it depends the power of germination of the seed which is 100 per cent. in a good sample. It was found that beads of moisture appeared on beans of the 1934 crop being packed for shipment to the Colonies even though a full month had been allowed for drying out in a well-ventilated barn.

The threshed beans should be turned into shallow bins, or spread out on a stone floor where ventilation is good. When thoroughly dry they should be put into loosely woven sacks holding about a bushel, and stored in a well-ventilated place. The beans should be sacked loosely so that movement may take place when the sacks are inverted. The condition of the seed should be noted occasionally, and if a tendency to heat is detected the sacks should be turned upside down. In countries where soya beans are dealt with in very large quantities the sacks are set in rows with open spaces between each with rows of



Threshing soya beans and baling the straw

sacks placed horizontally above them. The sacks are thus easily inverted if the beans tend to heat. It is, as a rule, not advisable to plant seed which is more than two years old unless it is known to have received proper attention during storage, or unless tests for germination are carried out before sowing.

Yields in various countries. The standard weight for the soya bean is 60 lb. per bushel. Yields depend upon the variety of seed, the condition of the soil, the rate of seeding, the adaptability of the seed to the locality in which it is grown, and to the manner of harvesting and threshing. The figures given by authorities in different countries vary considerably. Some state that a half to three-quarters of a ton is the average yield per acre in Manchuria; others state that the correct yield is over a ton. The official publication of South Manchurian Railways, *Progress in Manchuria* (1933), gives the average seed production as 20 bushels, and average yields of 16, 10, and 15 bushels per acre respectively for Japan, Korea, and China. Governmental Experiment Farms in South Africa have reported 34 bushels per acre. Canada reports 36 bushels per acre for seed yields. Reports from America state that crops under proper cultivation (grown for seed) yield from 30 to 40 bushels per acre, and a maximum yield of 50 bushels has been reported from North Carolina. Yields are stated to be highest when the crop is row-planted, and successive crops grown in the same soil give higher yields and better quality beans than first crops. The best results are obtained from varieties adapted to the localities in which they are grown, and it is shown that yields vary tremendously in different parts of the country, though the variety of seed is exactly the same. To explain this more clearly the yields of the 'Mammoth',

which is grown extensively in America, may be cited. Reports from different parts of the country give the following yields:

Mississippi	36 bushels per acre
North Carolina . . .	22 ,, ,,
South Carolina . . .	10 ,, ,,
Georgia	16 ,, ,,
Tennessee	23 ,, ,,
Maryland	9 ,, ,,

Maryland, which reports only 9 bushels per acre from the 'Mammoth', does better with 'Virginia', which yields 18 bushels per acre. The 'Haberlandt' in West Virginia yields 36 bushels, whilst in South Carolina it yields only 7 bushels. From this it will be seen how largely locality affects the soya bean, and how important it is that varieties should be adapted where possible. A report on seed yields from twenty-five different states, and dealing with twenty-two varieties, gave 38 bushels ('Morse') as the highest yield and 4 bushels ('Tarheel' Black) as the lowest.

Soya bean prices. The market value of soya beans c.i.f. Europe is constantly on the move. The price fluctuates so much that, over a period of nine years, it is found to be never the same for three consecutive months. The highest level reached since 1925 was in August of that year, when the price of a ton was £14 12*s.* 6*d.* Since that time the price has gradually dropped and in December 1933 it reached the low level of £5 17*s.* 6*d.* During the first week of August 1934, the price of soya beans per ton rose steadily and continued to soar for over a month. This was due in the first place to damage to the Manchurian crop caused by floods and, secondly, to the effect of drought in Germany. Owing to the poor condition of

PLATE 14

Loading soya beans for conveyance to the storage barns

	1925		
	£	*s.*	*d.*
Jan.	12	15	0
Feb.	12	5	0
March	11	7	6
April	12	0	0
May	12	17	6
June	13	0	0
July	13	5	0
August	14	12	6
Sept.	14	7	6
Oct.	13	15	0
Nov.	13	0	0
Dec.	13	0	0

Av 'age 'y price of Soya Beans ton

1926			1927			1928			1929			1930			1931			1932			1933		
£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
11	2	6	11	2	6	11	5	0	11	10	0	9	15	0	6	2	6	7	5	0	6	19	9
11	10	0	11	10	0	11	2	6	11	7	6	9	7	6	6	2	6	8	0	0	6	10	3
12	5	.0	11	5	0	11	5	0	11	5	0	9	0	0	6	12	6	7	0	0	6	8	9
12	0	0	11	5	0	11	7	6	11	5	0	9	10	0	6	7	6	6	10	0	6	4	9
12	0	0	11	12	6	11	10	0	11	2	6	9	0	0	6	6	3	6	15	0	6	10	0
12	15	0	11	15	0	11	12	6	10	15	0	8	5	0	6	5	0	6	11	3	6	17	6
12	17	6	11	5	0	11	11	3	11	10	0	8	13	9	6	5	0	6	16	3	6	15	6
12	5	0	11	0	0	11	17	6	11	17	6	8	15	0	5	15	0	8	1	3	6	3	9
11	15	0	11	5	0	11	12	6	12	1	3	8	1	3	5	18	9	7	15	0	6	7	6
11	2	6	11	5	0	11	15	0	11	7	6	7	6	3	6	15	0	7	10	0	6	3	6
11	5	0	11	3	9	12	0	0	10	11	3	7	2	6	7	2	6	7	10	0	6	1	6
11	0	0	11	6	3	12	2	6	10	5	0	6	13	9	7	3	9	7	5	0	5	17	6

root crops and pasturage, which had been adversely affected by the drought, the demand from Germany, which is the most important buyer, greatly increased. The price of soya beans during this period rose to £6 12*s*. 6*d*. per ton, while Manchurian beans afloat were £6 13*s*. 9*d*.

V

SOYA BEAN HAY

THE soya bean has other valuable uses for the farmer apart from the seeds obtained from it; it is one of the few annual legumes suitable for hay production. A considerable amount of soya is grown for hay in the United States, where it is generally conceded to be equal or even superior to red clover or the best lucerne. It is valuable because of its high content of digestible protein. Tests to compare the value of soya hay and lucerne as a source of protein in the production of milk showed that a large proportion of the necessary protein could be supplied as economically by soya hay as by expensive concentrates. It is used largely in the feeding of dairy cows, as a winter ration for young cattle and, fed at the rate of half total roughage, is a satisfactory feed for horses and mules. It also forms the basis of a ration for breeding flocks, and its value for fattening lambs is considered to be higher than good red clover.

Feeding values. The results of feeding tests carried out at various stations in the United States within the last two or three years will probably be of interest. The hay of some varieties of soya is distinctly superior to others, and perhaps this is the reason why reports of feeding value vary in different localities. A test to compare the feeding value of lucerne and soya hay was conducted with two groups of dairy heifers. The cattle fed lucerne consumed more hay than those fed soya, the latter refusing to eat the coarse, woody stems. This resulted in greater gains in body measurements in the group fed lucerne, but the average daily gains in live-weight were 1·37 lb.

for the cattle fed lucerne and 1·43 lb. for those fed soya. A report on the feeding value of soya hay stated that it was 6 per cent. more efficient for milk production and 7·8 per cent. more efficient for butterfat production than good quality lucerne. A less happy report came from another station, where milk production on soya hay ration averaged 1·1 lb. less and butterfat 0·02 lb. less per cow than on the lucerne ration. A reference to page 50, where yields of seed from the same variety grown in different localities are dealt with, indicates the possibility that the same peculiarity shows itself in the quality of hay grown in different districts. There is no doubt that the feeding value depends, to a large extent, on the quality of the hay. It is superior to lucerne for milk and butterfat production and the maintenance of body-weight only when of very high quality; poor and medium qualities are inferior in feeding value to lucerne. The chief objection to soya hay is the coarse, woody stems. Care exercised in the choice of a good forage seed, proper attention paid to time of harvesting, and a heavy rate of seeding do much to overcome this objection. Chopped and unchopped hay made little difference in a test for milk production but there was considerably less waste and the value of the chopped hay was increased by 23 per cent. For the farmer in need of good legume hay there are advantages in using most of his crop for hay and harvesting a portion only of seed for next year's sowing.

Solid drilling is usually recommended for hay production; it produces hay with finer stems and increases foliage, but under no circumstances should this method of seeding be used if the land is known to be weedy. Soya beans grow very slowly in the early stages, and heavy weed growth will quickly ruin the crop. The main objection to solid drilling in this country, for a few years at

The first English rick of soya hay, grown on
Fordson Estates in 1933

least, would be the larger amount of seed required. The soya bean yields from 2 to 3 tons of hay to the acre, and occasionally 4 tons. Under favourable conditions the amount should average at least two tons to the acre.

Time of cutting. Hay may be cut at any time after the pods have formed and until the leaves begin to turn colour. The best quality hay is, however, obtained about a month before the beans reach maturity, when the pods are well-formed but not ripe. Early cut hay is richer in protein but the yield is low and the hay more difficult to cure. Late cut hay is less valuable because protein decreases as maturity approaches. If cutting is delayed until the beans are ripe the leaves, which are the most valuable part of the hay, will have fallen, and by that time the stems are much too woody to be palatable. The variation in the composition of soya hay at different stages of growth is shown in the Table below. The analysis is reprinted from *The Soybean* and deals with the 'Mammoth Yellow' which is grown extensively in the United States.

Composition of soya hay at different stages of growth

Stage of growth	*Moisture*	*Protein*	*Fat*	*Nitrogen-free extract*	*Fibre*	*Ash*
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Full bloom .	5·11	19·22	1.45	38·56	26·50	9·16
Pods forming .	5·35	12·72	1·06	42·50	30·82	7·55
Seed half-developed .	5·40	10·31	2·34	44·73	30·45	6·77
Seed fully developed .	5·30	15·94	7·83	38·76	25·97	6·20

Soya hay plants are mowed like clover and handled much in the same way. Under good weather conditions cutting may begin as soon as the dew is off the plants, and they may lie in small piles in the field until the leaves and stems have wilted, but not long enough to become dry and brittle. A general crispness in the surface plants is the sign for raking in and stacking. Soya hay should be thoroughly cured before it is stacked or housed. A considerable amount of water will be present if the hay has been cut at the proper stage. Poles or logs centred in the stack for air circulation will do much to lessen the danger of spoiling while the unripe seed in the pods is drying out. Soya hay stands more weathering without materially reducing the feeding value than most hays, but, if stacked in the field, straw or other suitable material should be placed over the top to carry off the rain.

SOYA STRAW

The straw of the soya bean has value as roughage for all kinds of live stock. In the United States it is baled at the time of threshing and sold to stock-feeders. Its feeding value is stated to be higher than that of non-legume straws, and compared with the straws of wheat and oats is higher in protein and fat value. It is used in conjunction with other roughages for wintering dry dairy cattle and beef cattle. The lime and vitamins found in the hay are absent in the straw because the leaves are missing, so that decreased milk yields would result if the straw were fed to dairy cows as the only roughage over a long period; a portion of good legume hay is, therefore, fed with it. Soya straw has value, however, for dry cows, heifers, and sheep, and for fattening lambs and other live-stock if hay is fed with it occasionally. It is used on many farms in the United States for wintering idle work horses and

PLATE 16

Baled and trussed soya bean straw being ricked

Analyses of soya hay compared with those of other important hay crops

(Compiled by the Bureau of Chemistry and Soils, United States Department of Agriculture, Washington, D.C.)

Kind of hay	*Moisture*	*Ash*	*Crude protein*	CARBOHYDRATES		*Fat or ether extract*	*Digestible protein*	*Digestible carbohydrate equivalent*
				Crude fibre	*Nitrogen-free ext.*			
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Soya hay .	8·4	8·9	15·8	24·3	38·8	3·8	11·2	44·0
Lucerne .	8·3	8·9	16·0	27·1	37·1	2·6	11·5	42·0
Red clover	12·9	6·9	13·6	24·1	39·1	3·4	8·3	43·2
Timothy .	12·5	5·4	6·8	28·3	44·3	2·7	3·3	44·7

(The carbohydrate equivalent shown is the sum of the digestible crude fibre and nitrogen-free extract plus 2·25 times the digestible fat.)

other straws, and grain if necessary, are fed with it. In nutritive value soya straw is about equal to that of oat straw. Oat straw may rate higher on a tonnage basis when fed to idle, full-grown animals, for a fair amount of soya is wasted because of its coarse, woody character while good quality oat straw is usually eaten closely; in cases where straw is allowed to be picked over and trodden down it would seem that soya is best. If the straw is not needed as live-stock feed its high fertilizing value warrants it being put back on the land, but even this value is increased if returned in the form of manure.

SOYA IN THE MIXED CROP

There are many reasons why the soya crop ought to receive serious consideration in English farming plans. It occupies the land for four months only, whereas wheat and other cereals require nine months; it yields a seed which is much sought after for its oil and protein content; it provides an excellent feed for all classes of cattle; if properly handled it has great merit as a soil builder; it fits into rotation and mixed cropping plans and may precede wheat with very little further soil preparation, while it increases the fertility of the land for the succeeding crop. Soya beans were grown in the United States for a considerable number of years before a profit could be shown, notwithstanding the fact that the industry received the protection of a tariff. About 80 per cent. of the crop in that country is grown for forage and large areas are devoted to the mixed crop. Mixed crops including soya have not yet been tried in England, but there is considerable field for research and experiments should be well worth carrying out when it is decided which varieties are best for the purpose. In the United States soya is frequently, and profitably, substituted for oats in four-

Analyses of soya straw compared with those of other roughages

(Compiled by the Bureau of Chemistry and Soils, United States Department of Agriculture, Washington, D.C.)

Kind of straw	*Moisture*	*Ash*	*Crude protein*	CARBOHYDRATES *Crude fibre*	CARBOHYDRATES *Nitrogen-free ext.*	*Fat or ether extract*	*Digestible protein*	*Digestible carbohydrate equivalent*
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Soya straw	8·7	7·4	5·7	34·6	41·1	2·5	2·8	41·2
Wheat straw .	9·6	4·2	3·4	38·1	43·4	1·3	0·4	37·2
Oat straw .	9·2	5·1	4·0	37·0	42·4	2·3	1·2	40·3

(The carbohydrate equivalent shown is the sum of the digestible crude fibre and nitrogen-free extract plus 2·25 times the digestible fat.)

year rotations. Maize, soya, wheat, and clover; or clover (or early canning peas), soya, wheat, and clover appear in rotation in many parts of that country. It is grown in conjunction with maize, cow-peas (which we call field peas or green jackets), various grasses and sorghums for the production of well-balanced feed, and yields are often found to be better than when each crop is grown separately. The crop does well when sown in mixtures with sorghum and good quality hay is obtained; it is grown with maize alone and used for pasture and silage, or with field peas for hay and pasture, and it frequently appears as an orchard cover crop. The bean is palatable at almost all stages of growth, and it is, therefore, important among soiling crops. The range in maturity of different varieties, or the same variety planted later in the season, ensures a continuous supply of rich, green feed throughout the summer and autumn. It is preserved in the silo in its moist state, later to be balanced with corn as ensilage. Pasturing sheep on mixed crops of soya beans and corn is a common practice in the Corn Belt States. This mixed crop furnishes feed for fattening lambs for market and the sheep eat the weeds, soya beans and corn leaves before touching the corn ear itself. When grown for soil improvement pigs are turned on to the field before the crop is turned under. That all kinds of live stock eat the bean readily is not to be doubted. Many rows of promising plants disappeared from the Experimental Plots at Boreham during the 1933 season. The fluff, hair, and skin on the barbed wire fence, and the complete absence of all plants within reach told a story of fruitful, if painful, endeavour on the part of the cattle in the adjoining field!

VI

SOYA BEANS FOR SOIL IMPROVEMENT

EVERY farmer aims to bring about the permanent improvement of his land, and could sufficient quantities of farm-yard manure to furnish organic matter for the purpose be made available the matter might safely be left at this point. Unfortunately the real difficulty with farmyard manure is to get enough of it, and in order that natural fertility shall be restored and productiveness maintained and increased it becomes necessary to resort to artificial aids in the form of fertilizers which are expensive and only temporary in effect. It has long been recognized that land used for wheat is improved by growing legume crops which, by reason of the nitrogenous root residues, leave the land far richer in organic matter than it was before the crop was grown. The ploughing-in of a leguminous green crop results in an even greater accumulation of nitrogen for the succeeding crop and supplies the cheapest form of manuring. On light land poor in vegetable matter green manuring is of enormous value.

The soya bean grown as green manure to be turned under enriches the soil with nitrogenous compounds to a very large degree, and is more beneficial than the heaviest application of the best fertilizer. The crop is, however, too valuable when compared with other legumes commonly grown for this specific purpose to be turned under except under special circumstances. It can follow other early crops nevertheless, and furnish very valuable material for the benefit of succeeding crops. If properly grown and handled the soya bean will furnish more fertilizing matter than any other English-grown legume.

It is when the soya bean is grown in association with

its own strain of bacteria that the greatest benefit is derived by the soil. Soya plants plentifully supplied with nodules obtain the larger part of their nitrogen supply from the air and the remainder from the soil. If the land is already rich in nitrogen the bean will, like other legumes, obtain most of its nitrogen from the soil whether bacteria are present or otherwise. Bean plants appear to prefer this source of supply, and it is found that leguminous plants in soils rich in available nitrogen will, even though supplied with nitrogen-fixing bacteria, show no root nodules. Bacteria, like the rest of us, become idle in a land of plenty! They work to the best advantage on the poor, thin types of soil. The actual amount of soil improvement secured by growing the soya bean depends to a large extent upon the amount of top growth returned to the land. With the seed crop there is a large percentage of fallen leaves often amounting to one-third of the total weight of the tops. There are the vines (or straw) left after threshing, the roots, stems and humus generally—all of these contain nitrogen which, by the action of bacteria, is changed into a nitrate. When the whole of the crop above ground is removed, as is the case when the crop is grown for hay, very little organic matter is made as the larger part of the fertilizing constituents is removed in the tops. Some of the crop should be left behind, for it is only in this way that the soya bean, when grown for seed or hay, is of value to the soil. The beneficial effect of soya on the crop-producing power of the soil is much the same as that of clover and is, as stated above, proportional to the amount of top growth returned to the land. On certain sandy types of soil increased yields of subsequent crops have been reported even where the crop was harvested for hay. When the vines were left on the ground after threshing for seed the yield of the succeed-

ing crop was increased more than when the crop was cut for hay, but not so greatly as when the entire crop was ploughed under. Tests show that where inoculated soya beans were grown for hay the yield of following wheat was increased 3·5 bushels per acre over that where no soya beans were grown; when the entire crop was ploughed under the yield of following wheat was 6·6 bushels per acre more than when the beans were cut for hay.

In cases where it is desired to grow soya beans solely as green manure to restore poor land, the plants should be plentifully supplied with root nodules following proper inoculation, and the plants should not be allowed to become too mature before being turned under. Up to the time of flowering the nodules are exceedingly rich in nitrogen. Later, as pods form, the nitrogen content of the nodule decreases. For the maximum amount of benefit the crop should be turned under when the growth is most luxuriant which is at the end of the flowering period. Rolling first will facilitate the work of the plough. Immature vines decay far more rapidly than dry stalks, and less soil moisture is consumed when the crop is turned under early than is the case when the plants have thickened and coarsened. Lime assists in the decomposition of the humus in the soil and promotes nitrification; it is of great value when applied after green manuring. A ton of foreign beans costs about £6 at present-day prices. They would be useless for seed or hay production in this country but they have a distinct value if grown for soil improvement. If inoculated and drilled at the rate of three-quarters of a bushel per acre 50 acres of poor soil could eventually be made productive. When a soya crop is turned under for soil improvement the land should not be allowed to be bare during the following season.

VII

THE BY-PRODUCTS OF THE SOYA BEAN

THE most important by-product of the soya bean is the oil. Among the many varieties of the bean there is considerable variation in oil content and it may range from 12 to 24 per cent. A ton of beans having an average oil content of 17 per cent. yields about 380 lb. of oil. By the solvent method of extraction most of it is removed; the hydraulic crushing method removes about 75 per cent. The residues of the two methods of extraction are soya meal and soya cake. The former contains about 1 per cent. of oil, whilst the cake contains about 5½ per cent.: both are very valuable live-stock feeds. The price of soya oil, extracted by English mills and delivered in London, is £20 per ton at present-day prices, but a few years ago it was £35 per ton. In appearance the oil is similar to linseed. In the crude state it has a beany flavour and its colour ranges from yellow to brown, or from yellow to red, variation occurring here also according to the source and variety of the bean. After refining and deodorizing the oil is pale-yellow in colour and it is odourless and tasteless.

The oil and its uses. Soya oil is used for a number of industrial purposes, but perhaps no country has found so many uses for it as the United States. In that country it has become a strong competitor of all other vegetable oils, and it is becoming increasingly important in the paint industry. In the manufacture of lacquers, varnishes, and enamels it is considered to be as important as linseed oil and, although it cannot replace linseed entirely, it is frequently used as part of the substitute for it.

Soya oil belongs to the semi-drying group of oils and stands midway in its properties between linseed oil and cottonseed oil. Apart from its smooth flow, elastic film, and high gloss, it has the very valuable quality of rendering white permanent which makes it particularly suitable for use in enamels. It is claimed that no inferior qualities develop if the proportion of soya oil to the total oils does not exceed 25 to 50 per cent.

The largest consumers of soya oil in the United States are the soap-making and margarine industries. In the manufacture of soft soaps soya is replacing linseed entirely, and used in equal quantities with cottonseed it serves in the manufacture of hard soaps. The oil is used to some extent in the manufacture of rubber substitutes. It is used as salad and cooking oil in culinary operations. In the waterproofing of oilcloths and linoleums it has been found superior to linseed oil; it is stated to have a softer and more elastic film than the latter, and does not crack easily. Soya oil yields about 10 per cent. of glycerine as a by-product in the manufacture of soaps.

Notes on experiments in breeding for oil. Experiments in developing the drying capacity and quality of oil in the domestic bean are being carried out in the United States, where it is hoped that a superior quality oil having a more rapid drying property may eventually replace, in part, linseed which is relatively expensive, and most of which enters the country from outside sources. Increase of oil content is another important consideration in connexion with the improvement of the bean. The work of developing it to its full possibilities is only in its infancy; such a task entails an enormous amount of research work and years given up to experiment; but as the bean lends

itself very readily to improvement, many valuable new types should result in the course of time.

Some interesting findings have already followed upon experiments conducted with a view to raising the quantity and quality of the oil in the bean. It has been found, for instance, that selection is powerless to effect further improvement within pure strains of seed; or in other words, quantity and quality of oil can be controlled only to a certain extent by selection. When once the finest progeny from the best variety has been isolated, further selection cannot influence improvement in composition. Attempts to secure types with increased oil content by crossing with the same variety have been found to prove fruitless beyond a certain point, but it is thought that the crossing of varieties differing distinctly in oil content may give better results. Certain fertilizers have been found effective in increasing the quantity of oil. Climate is thought to be a more important factor than soil. Lime increases the protein content at the expense of oil. Late maturing varieties are said to give a better quality oil because the period for oil-formation occurs when the weather is cool, and this condition is more favourable for the proper development of the fatty acids which make for good quality oil. Geographical environment affects both quantity of oil and size of seed. In general, it is found that the percentage of oil content tends to decrease and the percentage of protein to increase as cultivation advances northward. The same variety of bean grown under northern conditions will give lower oil and higher protein than would be the case were it grown under southern conditions. Altitude also causes variation in oil content; soya beans grown in South Africa at 3,000 to 3,500 feet above sea-level contained 20·65 per cent. of oil as compared with 21·36 per cent. at 500 feet and 22·19 per cent.

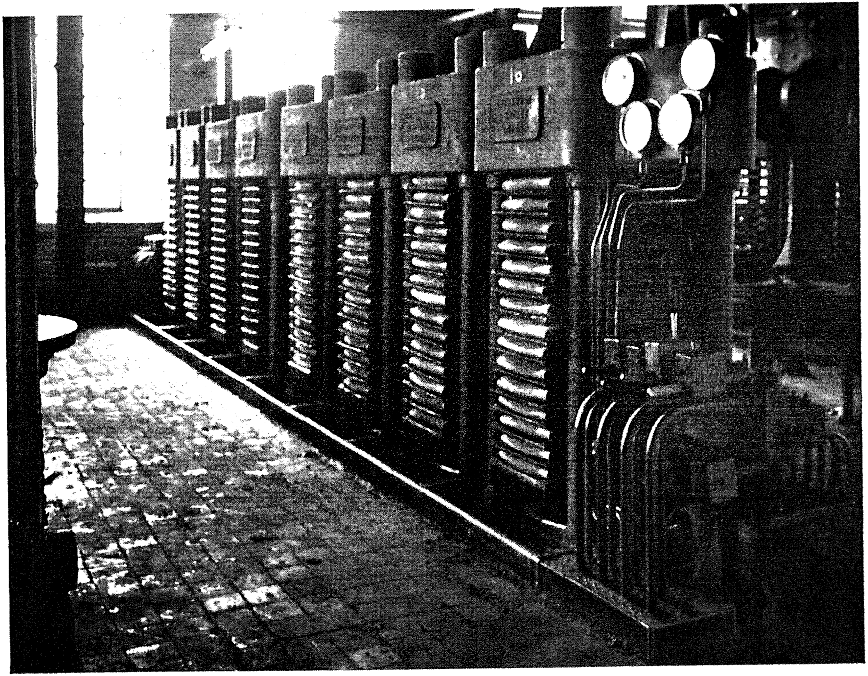
at 50 feet. Whether England, in the course of time, will be able to grow a bean of high oil content in her low-lying southern and eastern counties is yet to be discovered but, in connexion with this point, it is interesting to note that the 'C' variety grown in Essex showed a progressive movement in oil content from 14·66 per cent. in 1927 to 15·40 per cent. in 1933. The analysis of this bean grown in 1934 is given on page 27. In the case of the 'Jap' there was an increase in protein and a decrease in oil; the percentage of oil in 1932 was 13·77 per cent. and in 1933 13 per cent.

Although the value of an English-grown bean in Europe would depend to a large extent on the amount of oil contained in it, there is also a very large market for a bean of high protein content. Beans from the East have a more or less steady 17 per cent. oil content which yields about 16 per cent. of oil by solvent extraction. High oil yield and protein content are equally important, but until the former has been further developed (if it can be developed in this country) the grower of soya for oil extraction will do better with beans of average oil content and high seed capacity, growing on the principle of 'more beans, more oil' than with varieties of high oil content and low seed yield.

Great Britain's imports of crude soya oil for the years 1930–2 were 26,000 tons, 27,850 tons, and 27,343 tons respectively. These figures do not include the huge amounts of beans entering the country for oil extraction. Refined oil also enters the country but, owing to its inclusion with other refined vegetable oils, the exact amounts are not available. There is a steady demand in most countries for soya oil and increasing quantities of beans are imported every year for extraction purposes. There is also an inter-European trade in the export of

the extracted oil and the by-products, cake and meal. America's imports of oil, and beans for the extraction of it, have decreased as her domestic production of the bean has increased. Previous to 1922 her supplies came from the Orient, but during that year extraction of oil from the home-grown bean commenced. There was a very ready market for America's new product for many users of the imported oil had become dissatisfied because of its variable character and quality. As the milling industry has developed in America many new uses have been found for the oil. In 1931 America produced over 17,000 tons of oil from the domestic bean, and exported her surplus beans to Europe. This great success with soya encourages the belief that Great Britain could, in a few years, attain to a similar position with great benefit to her farmers, her oil industry, and trade in general. With a seed already acclimatized, with a farming community anxious to grow it, and the experience of America as a guide, such a goal is not out of reach.

Methods of extraction. Oil has always been of enormous value to the human race, and the art of rendering it may be said to date from the days of primitive man who roasted his 'kill' and collected the dripping fat for his further use. Oil rendering from fruits and seeds has been carried on from the earliest times by more or less crude methods, and the traveller to distant parts of the world will still find some of them in use. In Central Africa heaps of oleaginous fruits may still be seen melting in the heat of the sun while the oil exudes into collecting vessels. Grinding seeds in the mortar for oil is a method still in use in parts of India. Boiling out of oil was the method used at one time for extracting the fat from blubber on whaling-vessels. In Tuscany, at the present day, the



Heated cakes of crushed soya beans ready for pressing. In operating, the ram under each press forces the cakes upward, while the oil slowly exudes into the trays beneath

(By courtesy of Erith Oil Mills, Ltd.)

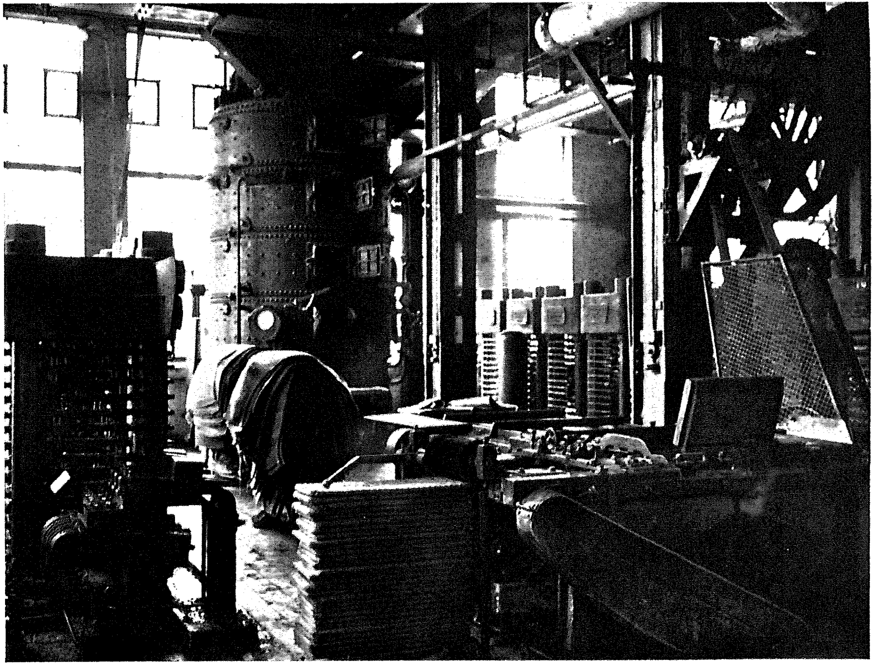
visitor may see olives ground under an enormous stone wheel attached to a central pole in a shallow stone basin, to which is attached a mule. These very primitive methods, and the very old presses which receive the pulp, sometimes produce three or four grades of oil. The ancient wedge-press may still be seen working for the production of oil from the soya bean in the smaller bean-producing areas of Manchuria. Large bean mills equipped with modern machinery have been erected at important centres, but in the native villages the wedge-press still holds its own. The beans are bruised and broken under a millstone, the resulting mass is put into bags and placed over boiling water to steam; they are then put into the press-frame and the wedges are driven home with hammers.

The press of modern times is a vast improvement on this old type of oil-press, although the principles involved are practically the same. The great advance in the oil-extraction industry was brought about by the invention of the hydraulic press in 1796 by Joseph Bramah, an English engineer, and all old methods in the western world immediately gave place to the new appliance. Until recent years all vegetable oils were obtained by submitting the seeds to pressure so that the oil was forced out, but always a certain amount of oil was left behind. The method of solvent extraction has latterly also been developed and by this means nearly all the oil is removed. The solvent method is largely in use in many parts of the world. American mills employ the hydraulic press for oil extraction, and very little extracted meal is produced.

Most people know something of the methods employed for the extraction of oil from oil-bearing seeds, but it may be that few know exactly how the oil is obtained. The

writer visited the Erith Oil Works, Limited, in order to see the oil extracted, and the manner of producing soya meal and cake; a short description of the two processes, hydraulic press and solvent extraction, may be of interest.

When the hydraulic press is used for oil production the residual mass of crushed seed is formed into cattle cakes. The beans are first broken roughly and passed over grooved and smooth rollers, where, by successive crushings, they are reduced on a progressive scale to the requisite fineness. In passing through the rollers the oil-cells of the beans are broken so that the oil is rendered more available under pressure. On passing the final roller the ground beans are discharged into a 'cooker' to be heated and tempered. Heating is a most important factor in the process for it is upon the condition of the heated meal as it emerges from the 'cooker' that the yield and quality of the oil will depend. Moisture content, agitator speed, the amount of time allowed and the temperature have all to be carefully regulated. When ready, the heated, crushed beans are discharged from the 'cooker' in single batches about 30 inches by 12 inches in size on to coarse, stiff press-cloths with loose ends; the ends are quickly folded over, and the hot slab of oily meal is passed immediately, by hand labour, into the open presses at the side. These presses are fitted with a number of corrugated iron plates placed one above the other after the manner of the trays in an ordinary cooking oven. As the presses are filled, the ram under each one rises, automatically crushing the cakes against the head of the press. Pressures of from 400 to 4,000 lb. to the square inch are reached according to requirements. As the pressure increases the oil slowly exudes from the hot cakes, flows on to the pressplates and drops into a trough built round the base of the press. From this point, the oil, which is of a



Soya bean cakes, after leaving the press, are passed through a paring machine where the edges are trimmed. The cakes seen in the illustration are ready for market and contain $5\frac{1}{2}$ % oil and 43 % albuminoids

(By courtesy of Erith Oil Mills, Ltd.)

deep red colour, runs down into an intermediate storage tank to be filtered. When the flow of oil ceases the cakes are removed from the press and passed into a paring-machine, where the edges, which still contain a considerable quantity of oil, are trimmed off and returned to be pressed again with fresh cakes. The cake is now ready for use in live-stock feeding, where it is of great value if used with discretion. Soya cake contains approximately 5 per cent. of oil, and about 1,900 lb. is obtained from a ton of beans by the hydraulic press method. The present-day price in London is about £8 per ton.

The solvent process is the alternate method of extraction. The principle advantage is that it removes a greater percentage of the total oil and, with materials such as seeds and beans which have a comparatively low oil content, it is imperative that the maximum amount be extracted if the operation is to be profitable. The oil removed by the use of solvent is equally suitable for refining as that obtained by hydraulic press. Special grades of petroleum spirit are manufactured for use as edible oil solvents. The residual meal, owing to its lower oil content, makes a very satisfactory stock feed. At one time there was a strong prejudice against meal extracted by solvent. Cases of cattle poisoning were thought to have been caused by the use of soya meal produced by solvent leaving a residual poison behind. Investigations followed and, although no conclusive evidence was available, it was established that the poison might have been caused by the incomplete removal of the solvent. In present-day methods of extraction the solvents are highly refined, and are easily and completely removed, and the meal is entirely free from solvent odour.

The beans are prepared in a similar manner to that used in the hydraulic press method, except that they are

reduced to fine flakes by the rollers. The flaked seed is fed into a series of vessels which, when filled, are sealed and charged with solvent. The oil is recovered from the solvent by distilling off the latter and, without further alteration in its properties, the solvent may be used repeatedly. Soya meal contains about 1 per cent. of oil and, after drying (or after further grinding if required) it is ready for sale at about £8 15*s*. per ton for the use of stock-feeders or for the manufacture of compound foods for both cattle and poultry.

Soya cake and meal. Soya cake and meal are valuable protein supplements in cattle feeding; both are richer in protein than the best grades of cottonseed or linseed meals. The meal may, weight for weight, replace other high-priced protein cakes in the concentrate ration. It is high in total digestible nutrients and compares favourably with all other oil-meals. It is included in dairy and cattle rations, in sheep and lambs' food, for fattening stock and in pig-feeding. There is plenty of evidence as to the efficiency of soya meal in live-stock feeding, yet it does not appear to be used in this country as widely as its feeding value merits. The prejudice formed when it was first introduced in England as dairy food seems still to exist. It was thought at that time that the use of the meal might affect the taste of milk and butter; but, although this was disproved later, England remains a small user. A few farmers here and there throughout the country employ it in the ration, but inquiry elicits the information that many have tried it and found it unsatisfactory, which may have been due to the manner of feeding. As with other concentrated foods, certain precautions as to the amounts fed must be observed if digestive troubles, due to the high protein content, are to be

avoided. Used in the right quantities in mixed rations it gives excellent results, and may quite usefully replace the more expensive concentrates which farmers cannot afford to buy. Soya cake should also be used with discretion, and greater care should be exercised in the amounts used because of its high oil content. It may be substituted for linseed cake in cases where the latter is used for laxative purposes. A comparison of the digestibility of soya meal and other oil-meals is given below.

Comparison of the digestibility of various oil-meals

(Reprinted from *The Soybean*)

Kind of meal	*Protein*	*Fat*	*Nitrogen-free extract*	*Fibre*	*Total digestibility*	*Assimilability*	*Digestible albuminoids*	*Starch equivalent*
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Soybean (pressed) .	39·2	4·4	25·6	5·5	90·0	96·0	38·4	74·7
,, (extracted)	41·6	1·4	27·5	7·2	97·0	96·0	40·7	73·0
Cottonseed (decorticated) . .	39·7	8·4	15·3	2·0	76·0	97·0	38·0	71·0
Linseed (pressed) .	28·8	7·9	25·4	4·3	79·0	97·0	27·2	71·8
,, (extracted)	32·2	3·4	26·2	4·5	78·0	96·0	31·4	64·8

Results of comparative feeding tests. A short outline of the results obtained in cattle feeding trials in Great Britain and various other countries may be of use in supplying further information to farmers already employing soya in the ration, and in helping those who are interested yet uncertain of its effect upon their live-stock. During the years 1926 to 1931 a series of experiments in pig-feeding with rations including soya meal was carried out by the Harper Adams College

Experimental Station in Shropshire. A full report of the results appeared in the *Journal of the Royal Agricultural Society of England* (vol. xcii, 1932). The conclusions reached in two particular lines of research are of special interest: (*a*) the experiments conducted to determine whether a rich protein vegetable food such as soya bean meal might satisfactorily replace the more expensive animal protein foods, and (*b*) the experiments carried out with a view to finding the correct proportion of soya meal in the ration, and the amounts of mineral supplement required to make it fully effective.

In the first case, it was found that when mineral deficiency is made good, extracted soya meal is fully as efficient as any other protein concentrate commonly used in pig feeding, and that it gives as good results as fish or meat meals when added to the cereal ration. It was further stated that in view of its relative cheapness and efficiency soya meal, except in a few special cases, was the only protein concentrate used for all classes of pigs, both for breeding and feeding, during the last three years of the course at the College.

In the second case, it was found that an average proportion of about 8 per cent. in the ration was sufficient, and that this proportion was best obtained by allowing about 12 per cent. to the newly weaned pig and gradually reducing the amount to about 5 per cent. at bacon weight. Limestone and salt was stated to be the only minerals required in the soya ration and that $1\frac{1}{2}$ lb. of limestone and $\frac{1}{2}$ lb. of salt, or even less, per 100 lb. mixed meals would give quite as satisfactory results as fish meal. The 8 per cent. average proportion of soya in the ration is low when compared with the amounts used by some farmers. Soya meal up to 25 per cent. is stated by a farmer in Essex to be the amount used by himself in pig

feeding. His pigs appeared to be in perfect condition and at four months weighed 128 lb. per head, whilst those of the same age fed ordinary ration not containing soya weighed 102 lb. per head. Whether it is good policy to feed large amounts when smaller ones will suffice is a question to be answered by the individual from his own experience.

Practical feeding trials with bullocks and dairy cows were carried out several years ago at various agricultural institutions in Great Britain to compare the feeding value of soya cake and meal with that of decorticated cotton-cake and linseed cake. The following notes were drawn from 'Monthly Notes on Feeding Stuffs' which appeared in the *Journal of the Ministry of Agriculture* (vol. xxx, No. 9). Soya meal was considered to be equivalent to linseed cake for dairy cows, and gave better quality milk judged on the fat and butter tests. Soya cake was considered to be an effective substitute for decorticated cotton-cake but, owing to its rich protein and fat content, should not exceed 6 lb. per head per day. It was stated that unless milk was pasteurized before distribution an allowance of more than 2 lb. of cake per head per day was not advisable. In feeding trials with bullocks it was concluded that soya cake was a good beef producer and a healthy cattle food which could be fed with safety up to 5 lb. per head per day, but that weight for weight it was not equal to linseed cake as a meat producer. The allowance of soya cake and meal was stated to be as follows: milch cows up to 3 lb. per head per day; horses 3 lb.; fattening cattle up to 4 lb., and fattening sheep and pigs up to 1 lb. per head per day. It was further stated that soya cake or meal may be usefully included in all lambs' food, sheep foods, pig meals, and cattle cake mixtures.

A good deal of experimental work with soya meal and cake in stock-feeding has been carried out both in the United States and Europe. The approximate amounts of soya meal used daily in the ration in the leading dairy countries of Europe in 1931 were 3½ lb. per head in the Netherlands; 3 lb. per head in Denmark, and just over 1 lb. per head in Germany. Comparisons made between cottonseed meal and soya meal demonstrated that the latter resulted in more milk, less but richer cream, and butter of a superior quality. With cottonseed meal the butter was harder but of a greasy texture, whilst soya meal butter, although of a higher colour, was more agreeable both in texture and flavour. With regard to increased yields of milk and butter a difference of 5 per cent. appeared in favour of soya meal as compared with cottonseed meal. Tests of the value of soya cake and decorticated cottonseed cake found a slight advantage with regard to milk production but small enough to make the two cakes equal; the cows gained more in weight on soya cake, and no difference in laxative effect was found. Trials conducted to determine the amount of soya cake in the ration found that 2·2 lb. of soya cake replaced the same amount of other high protein cakes without affecting the condition of the cows, the production of milk, or its constituents; and that when good, fresh cakes were fed no detrimental influence was traceable in the flavour or odour of the milk or butter.

Soya beans, whole or ground, are used to a certain extent in the United States for fattening stock but, in view of the very high oil content, it is found very necessary to feed in small quantities well balanced with other foodstuffs. For beef production the beans are mixed with other grains and form the protein part of the ration.

Ground beans do not keep well without becoming rancid because of the presence of so much oil, and for the same reason they do not grind well unless mixed with other cereals. The value of the ground bean in the ration for fattening cattle is shown by the results obtained in a series of trials conducted with two- and three-year-old cattle wherein one group received cottonseed meal, and the other ground soya beans as a supplement to the ration. The supplement was fed at the rate of 2·5 lb. daily per 1,000 lb. live-weight. The results were not entirely satisfactory. It was found that the ground beans were quite as efficient as cottonseed meal as long as they were eaten readily, but towards the end of the period a falling off in appetite appeared in the group, and as palatability decreased so was efficiency lessened. There was also a marked laxative effect due to the heavy percentage of fat in the ground beans. The profit per head was slightly in favour of the ground bean group if the beans were valued at the same price per ton as the cottonseed meal. On the whole, the results obtained from the various experiments with beans, either ground or whole, are poor in comparison with those obtained from the meal and cake, and there is now only a limited use for them. Trials with the bean as a protein supplement for breeding sows during gestation and lactation found that the condition of the animals was materially improved, and that the better state of nutrition was reflected in the young pigs. Up to the present, there appears to be no evidence to prove that ground or whole beans fed to brood sows affects the quality of the pork from the pigs raised. Several years ago soft pork began to find its way on to the American food markets. Hams when cured were greasy and lacking in firmness; lard remained a semi-liquid oil not hardening at freezing temperature. On investigation

it was found to have been caused by unlimited feeding with soya beans. The high oil content of soya beans, which is so valuable commercially, is a definite handicap to extensive use in pig feeding, and because of the detrimental effect on pork should not be fed in rations to pigs fattening for the food markets. Soya bean meal and compound foods containing the meal have been used for many years in poultry feeding for both growing chicks and hens. Comparative trials on the value of protein feeding-stuffs from animal and vegetable sources found that soya meal, with a suitable mixture, ranked first in the order of egg production for vegetable proteins, and compared very favourably with the average meat scrap ration. Many farmers in the United States soak and cook the whole bean and find them quite as satisfactory as the meal provided a mineral mixture is added.

When the value of soya meal becomes properly understood for the production of beef and butter, and for livestock feeding generally, there is no doubt that there will be practically an unlimited demand for it as feed.

VIII

FOOD PRODUCTS OF THE SOYA BEAN

THE soya bean as a human food material has been receiving serious attention both in America and Europe because of its remarkable richness in protein and fat. In the diet of Western peoples protein is derived mainly from the animal and vegetable kingdoms and supplied in the form of meat, milk, eggs, and bread which are relatively expensive, it cannot be taken as freely as it should be by those of limited means. The soya bean, which is rich in all the ingredients entering into the composition of these four foods, offers a means whereby a cheaper source of protein may be made available. The possibility of replacing animal proteins with those of the vegetable kingdom has been the study of scientists for many years, so that vegetable foods containing protein of value are more familiar in our markets to-day than was the case a few years ago.

It is unfortunate that the inherent conservatism of English people to anything new has been the cause of past failures to popularize soya bean food products for consumption in this country. The bean contains iron, magnesium, calcium, and other mineral salts; phosphorus in the form of lecithin makes it valuable in cases of nervous disorders; it is a muscle-builder combating malnutrition and has been used with great success in balancing the diet of children whose food has been deficient in the essentials necessary for promoting normal growth and proper development.

A well-balanced and physiologically satisfactory diet must contain all the essentials required for building up

the body and maintaining it in good health. Such a diet includes proteins, fats, carbohydrates, minerals, water, and vitamins. Further, the actual value of a food material depends upon the kind and amount of nutrient contained in it; upon the ease with which it may be digested and, finally, upon the proportion of nutrient that will be actually digested and absorbed. The results of investigations into the nutritive efficiency, the degree of digestibility, and the extent to which it is assimilated prove that the soya bean, when properly prepared as food, is of exceptionally high value. There can be no doubt of it when the Chinese, who make practically no use of dairy products and very little of meat, have existed for centuries by means of it; it appears to have provided them with a singularly well-balanced diet throughout the ages.

It has been stated that the soya bean is the most nearly perfect vegetable substitute for meat. Its protein yield is twice that of meat; more than twice that of eggs, wheat, and other cereals; six times that of bread, and twelve times that of milk. Although it has been utilized in the preparation of food products for so many centuries in the East, it is only within comparatively recent years that it has taken a place in the diet of the peoples of the West. In America, for instance, numerous food industries with soya as the base of their products have developed, and much of her home-grown soya oil is used in edible products such as margarine, lard substitute, mayonnaise, refined edible oils, and salad oils. Cocoa, fountain drinks, various sweetmeats, chocolates, cakes and buns, cheese, sausages, and bread are made in the United States from the soya bean. Soya flour is milled and used with other cereal flours in the manufacture of breakfast foods, beverages and preparations for infants and invalids. Soya flour

made into gruel has been found to be a very valuable food in the dietary of infants. Soya 'sprouts', which have been grown and used for centuries in the East, have recently been introduced as a green vegetable. The beans gathered before ripe and prepared in the same manner as green peas are a very satisfactory vegetable and the dried beans, if soaked for forty-eight hours, may be cooked like haricot or butter beans and make a most delicious and nutritious vegetable dish. Complete meals consisting of preparations made from the soya bean are a feature of some food establishments in America.

Europe has not yet reached this point in utilizing the soya bean, but there is no doubt whatever that its products are gradually becoming established in Western countries. We eat of its 'fruits' without knowing it! The bean, when properly prepared by roasting, makes an excellent cereal beverage which looks, smells, and tastes like coffee; a sauce, appropriately seasoned with spices, is the so-called 'Worcester Sauce', and soya soups made from the bean taste like beef extract. During the late war, when Germany found herself on the verge of starvation, glutamic acid, produced from the soya bean, was used in German hospitals to form the basis of beef-tea, and it is said that the ground bean also was used at that time for the making of bread.

Soya bread, made from properly prepared flour, is obtainable in England and is stated to be of high nutritive value. When combined with cereal flours the fat of the soya bean prevents the bread from drying so that it remains fresh for many days. Bread made with the addition of soya flour has a more attractive appearance and contains more nourishing food properties than that made with cereal flour mixed with potatoes and other ingredients of the same type, and it has a more pleasing flavour.

Soya flour has not yet come into line with other cereal flours in this country but it has, for many years, been used in the preparation of food materials for diabetic persons requiring a low starch diet. The flour contains more protein and fat, and less carbohydrates than ordinary cereal flours, and a certain variety manufactured in England is stated by the proprietors to contain 42 per cent. protein and 20 per cent. fat, having good keeping qualities, 0·13 per cent. lecithin phosphoric acid and the vitamins A, B, D, and E. There are many food products on the London market under names that conceal their soya bean origin. Just before the late war an enterprising English firm was making great strides with soya products. Vegetable butter, biscuits, cocoa, milk chocolates and other confectionery, cream, cakes, bread, &c., proved quite a success until a war-time embargo placed upon the importation of soya beans put a stop to the business; the organizers eventually went to America!

One of the staple foods of the people which cannot be dispensed with is milk. It contains in balanced form all the substances necessary for the proper maintenance of the human body. Unfortunately, it is particularly liable to contamination by disease germs. A Report of the Medical Research Council issued towards the latter end of 1933 stated that there was a 16 per cent. infection of raw milk coming from mixed herds, and that in bulked milk contained in receiving tanks at creameries a 37 per cent. infection was found. There is a great deal, therefore, to be said in favour of vegetable milk which is germ-free. In 1932 a 'milk' was made from English-grown soya beans which had the appearance and consistency of cow's milk, and kept fresh for five days! In the East soya 'milk' is prepared by soaking the beans in water, crush-

ing them and boiling—and the taste, to Western palates, would be nauseating to say the least. The perfected method of producing the 'milk' is considerably more involved and the resulting liquid is as smooth as cow's milk, and keeps fresh much longer. By evaporation it can be reduced to powder in which state it keeps indefinitely, and by the addition of water it may be returned to its original liquid state without change of flavour or loss of vitamins. The amino acids of soya are very similar to those of cow's milk and on digestion the protein yields a complete amino-acid mixture. Although never likely to replace cow's milk, except in the strictest vegetarian diet, milk from the soya bean is more easily digested and for this reason it has been used successfully in feeding of ailing infants and other invalids incapable of assimilating cow's milk.

The soya bean is by far the most valuable of all known beans and our farmers ought to make a serious effort to grow it. It has already been shown that the acclimatized bean will grow in this country, and if crops can be raised profitably and on a commercial basis, a service will be rendered both to the farmer himself and to the country. With memories of the convoyed food ships of war-time; of the appalling losses due to enemy submarines, and the anxiety for the safe arrival in our ports of those ships which had escaped the danger, it would be comforting to know that in the soya bean, which provides a green vegetable, flour for bread, and a substitute for meat and milk, we should have an assurance against starvation.